

PLYMOUTH HARBOR  
MASSACHUSETTS

DESIGN MEMORANDUM  
ON  
BREAKWATER AND ANCHORAGE

11/18/65  
11/18/65  
11/18/65

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND  
CORPS OF ENGINEERS WALTHAM, MASS.

September 1965

Revised 2/66

NEDED-R (8 Oct 65)

2nd Ind

SUBJECT: Design Memorandum on Plymouth Harbor, Massachusetts

U. S. Army Engineer Division, New England, Waltham, Mass. 21 Feb 1966

TO: Chief of Engineers, ATTN: ENGCW-EZ

1. Re: Paragraph a. The requested stability studies are shown on Plates Nos. A-1 through A-4 included in the accompanying copies of the revised Design Memorandum. These studies were made on a typical section having a bottom elevation of -8.0, since it is likely that this section will result from overdepth dredging, and settlement and displacement of the underlying foundation materials during construction of the breakwater. The shear strength of the underlying foundation soils as used in the studies was determined from laboratory tests on undisturbed samples obtained from foundation boring FD-13. Results of shear and consolidation tests are shown on Plates Nos. A-5 through A-8, included in the accompanying copies of the revised Design Memorandum.

2. As shown by the analyses, the minimum factors of safety obtained are 1.5 by the wedge method of analysis and 1.45 by the circular arc method. These values are considered satisfactory. Analyses for the case of bottom elevation at -5.0 m. l. w. indicate higher factors of safety.

3. Re: Paragraph b. The use of bank run gravel as a bedding layer beneath the quarry run stone bedding course, to limit penetration of the soft organic silts into the bedding course, as recommended, has been evaluated and is concurred in. Therefore, a bedding layer of bank run gravel, 2 feet thick, has been incorporated into the design section.

4. The Design Memorandum dated September 1965, as submitted to the OCE by letter of 8 October 1965, has been revised to; (1) up-date to February 1966 information relating to the project, (2) include the stability studies as requested, and (3) include a breakwater design change as suggested providing for a bedding layer of bank-run gravel, two foot thick. Numerous pages in the original Design Memorandum were revised to reflect the foregoing changes, therefore, rather than submit only the revised pages we have prepared and inclose ten (10) complete copies of a Design Memorandum, Revised, February 1966, for your further review and approval.

Incl  
as (10 Cys)

REMI O. RENIER  
Colonel, Corps of Engineers  
Acting Division Engineer

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND  
CORPS OF ENGINEERS

424 TRAPELO ROAD  
WALTHAM, MASS. 02154

ADDRESS REPLY TO:  
DIVISION ENGINEER

REFER TO FILE NO. NEDED-R

30 September 1965

DESIGN MEMORANDUM  
BREAKWATER AND ANCHORAGE  
PLYMOUTH HARBOR, MASSACHUSETTS

PERTINENT DATA

1. Purpose. To design a project plan which will provide a breakwater and protected anchorage to serve adequately the needs of present and prospective navigation interests in Plymouth Harbor, to include facilities for sport fishing from the breakwater, and to determine the economic justification of such a plan.

2. Location. - Within the Town of Plymouth about 45 miles south of Boston Harbor and about 15 miles north of the easterly entrance of the Cape Cod Canal.

3. Recommended Project Plan . -

a. Includes uncompleted project modification, authorized by the River and Harbor Act of 23 October 1962, consisting of the construction of a rubble stone breakwater about 3500 feet long, an anchorage 8 feet deep and 60 acres in area inside the breakwater, and

b. A recreational development, to provide for sport fishing from the breakwater, consisting of a stone causeway about 360 feet long from the westerly end of the breakwater to the land, a guard rail along the top of the breakwater and causeway, a foot-bridge spanning a navigation opening through the breakwater, and public access, parking and sanitary facilities for sport fishermen use.

4. Estimated First Cost of Construction. -

Navigation

Channels

Dredging (for anchorage)

649,000 c.y. @ \$1.05

\$682,000

Estimated First Cost of Construction (Cont'd)

Contingencies @ 12%	<u>81,800</u>	
Total Dredging (anchorage only) Contract Cost		\$ 763,800
Breakwater		
Dredging (for foundation)		
50,000 c.y. @\$1.05	52,500	
Stone 180,000 ton @ \$5.60	1,008,000	
Gravel Borrow 28,500 ton @\$2.80	79,800	
Causeway stone		
8,100 ton @ \$5.20	<u>42,100<sup>(1)</sup></u>	
	\$1,182,400	
Contingencies @ 12%	<u>141,900</u>	
Total Contract Cost (Navi- gation Features)		<u>\$1,324,300</u>
Total Contract Cost		\$2,088,100
Engineering & Design		64,000 <sup>(2)</sup>
Supervision & Administration		<u>138,000</u>
Total Cost (Corps of Engr's Funds & Non-Fed. Contributions)		\$2,290,100
	say	\$2,290,000
Aids to Navigation (Coast Guard)		<u>\$ 1,000</u>
Total Navigation Project Cost		\$2,291,000

(1) Breakwater stone prices based on use of land equipment rather than waterborne equipment to effect a substantially lessened contract cost. This method will require a causeway to the breakwater with a top elevation of about El. +10.6, therefore causeway stone below this elevation charged to navigation aspect of project while causeway stone above this elevation is charged to recreational development aspect.

(2) Exclusive of \$10,000 Preauthorization Studies

## Recreational Development (Sport Fishing)

### On-project Features

Breakwater stone	1300 ton @ \$5.60	\$ 7,300 <sup>(1)</sup>	
Causeway stone	1400 ton @ \$5.20	7,300 <sup>(2)</sup>	
Guard-rail	3800 l. f. @ \$2.00	7,600	
Foot-bridge	1. s.	6,500	
		<u>\$28,700</u>	
Contingencies @ 12%		3,400	
Total Contract Costs (Recreat. Dev. Features)			\$32,100
Engineering & Design			say \$32,000
Supervision & Administration			1,000
			<u>2,000</u>
Total-Corps of Engr's Funds & Non-Federal Contribution			\$35,000

### Off-site Features

Parking areas, public access lands, sanitary facilities	<u>20,000</u>
Total Recreational Development Costs	<u>\$55,000</u>

- (1) Stone in breakwater, above elev. +10.6, widened by 2 ft. to facilitate sport-fishing use.
- (2) Stone in causeway, above elev. +10.6, to facilitate sport fishing use (See note (1) under Navigation).

### Summary - Est. First Cost of Project Construction

Navigation Features	\$2,291,000
Recreational Development (Sport Fishing) Features	<u>55,000</u>
Total	\$2,345,000

### 5. Benefits

#### Navigation

	<u>General</u>	<u>Local</u>	<u>Total</u>
<u>Fishing Industry</u>			
Increased fish catch	\$46,500	-	\$46,500
Saving in trucking	15,700	-	15,700
Reduction in boat damage	6,000	-	6,000
Increased lobster catch	13,750	-	13,750

## 5. Benefits (Cont'd)

	<u>General</u>	<u>Local</u>	<u>Total</u>
<u>Recreational Boats</u>			
Local fleet (incre. use, gradual growth)	\$ 13,550	\$13,550	\$ 27,100
New Boats	6,400	6,400	12,800
Present & anticipated transient boats	2,650	2,650	5,300
Reduction in boat damage	<u>3,000</u>	<u>3,000</u>	<u>6,000</u>
Total Navigation Benefits	\$107,550	\$25,600	\$133,150
Percentage	81%	19%	100%
<u>Recreational Development</u>			
Sport-fishing from break- water	<u>15,000</u>	<u>15,000</u>	<u>30,000</u>
Total Navigation & Recr. Dev. Benefits	\$122,550	\$40,600	\$163,150
Percentage	75%	25%	100%
Area Redevelopment Benefits			<u>5,700</u>
Total Project Benefits			\$168,850
			say \$169,000

## 6. Cost Apportionment

### Navigation

Federal	Corps of Engineers -80% of \$2,290,000	\$1,832,000
	U.S. Coast Guard -	<u>1,000</u>
	Total Federal	\$1,833,000
Non-Federal	20% of \$2,290,000	<u>458,000</u>
	Total	\$2,291,000

Recreational Development (Sport Fishing)

Federal: Corps of Engineers 50% of \$55,000	\$27,500
Non-Federal: 50 % of \$55,000 = \$27,500	
less credit for off-site public access lands, & parking & sanitary facilities	<u>20,000</u>
Non-Federal cash contribution	<u>7,500</u>
Total	\$35,000

Total Corps of Engineers Costs	\$1,860,000
Total U.S. Coast Guard Costs	1,000
Total Non-Federal Contributions	<u>465,000</u>
Total	\$2,326,000

7. Annual Charges

Navigation

Federal

Corps of Engineers

Interest & Amort.

(\$1,860,000 x .03979) \$74,000

Maintenance-breakwater \$10,000

-anchorage

dredging 10,000

20,000

\$ 94,000

U.S. Coast Guard

Interest & Amort.

(\$1,000 x .03979) 40

Maintenance-Aids to Navigation 160

200

Total Federal \$ 94,200

Non-Federal

Interest & Amort.

(\$458,000 x .03979) 18,200

Total Navigation Annual  
Charges

\$112,400

### Annual Charges (Cont'd)

#### Recreational Development (Sport Fishing)

##### Federal-Corps of Engineers

Interest & Amort.

(\$27,500 x .03979) \$1,100

Maintenance-to footbridge \$1,000

to guardrail 1,000

2,000

Total Federal \$ 3,100

##### Non-Federal

Interest & Amort.

(\$27,500 x .03979) \$1,000<sup>(1)</sup>

Total Non-Federal 1,100<sup>(1)</sup>

Total Annual Charges-for recreational development 4,200

Total Annual Charges-for navigation features 112,400

Total Annual Charges for Project \$116,600

(1) Local maintenance and operations costs, estimated at \$5,000, are expected to be self-liquidating.

### 8. Benefit-Cost Ratios

Navigation features only -\$133,150/\$112,400 = 1.2

Recreational Development features only -\$30,000/\$4,200 = 7.1

Project Plan (w/o Area Redevelopment Benefits) -\$163,150/\$116,000 = 1.4

Project Plan (with Area Redevelopment Benefits) -\$169,000/\$116,600 = 1.4

### 9. Requirements of Local Cooperation

Navigation Features - In accordance with terms of authorizing document:

a. Contribute in cash 20 percent of the first cost of construction, such contribution, then estimated (in 1962) at \$300,000, to be paid in a lump sum prior to initiation of construction, subject to final adjustment after annual costs have been determined; and

b. Maintain existing public landings open to all on equal



terms and provide without cost to the United States all necessary mooring facilities in the anchorage; and

c. Provide without cost to the United States all lands, easements, and rights-of-way necessary for construction and subsequent maintenance of the project and of aids to navigation upon the request of the Chief of Engineers, including suitable areas determined by the Chief of Engineers to be required in the general public interest for initial and subsequent disposal of spoil and necessary retaining dikes, bulkheads, and embankments thereof or the costs of such retaining works; and

d. Hold and save the United States free from damages due to the construction and subsequent maintenance of the project.

Recreational Development Features-Additional requirements recommended.

e. Contribute in cash 50 percent of the first cost of construction of the on-site project recreational development features, less the value of locally furnished basic facilities required to provide for sport fishing from the breakwater, e. g., public access, parking and sanitation facilities.

f. Provide, without cost to the United States, a public right-of-way at least 15 feet wide extending a distance of about 400 feet from Water Street to the westerly end of the breakwater.

g. Provide, operate and maintain, without cost to the United States, adequate parking and sanitation facilities, within a reasonable distance of the breakwater, to accommodate, on equal terms, all those fishermen using the breakwater during the estimated project life of 50 years.

h. Hold and save the United States free from damages resulting from personal injury to any person while engaged in fishing from the breakwater, with the understanding that the Town of Plymouth is authorized to police, regulate, restrict or limit, in the interest of public safety, the use of the breakwater, for sport fishing activities, providing that such regulations, restrictions and limitations are applicable to all on equal terms.

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CORPS OF ENGINEERS  
424 TRAPELO ROAD  
WALTHAM, MASS. 02154

ADDRESS REPLY TO:  
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REFER TO FILE NO. NEDED-R

30 September 1965

PLYMOUTH HARBOR  
MASSACHUSETTS

DESIGN MEMORANDUM

PROJECT AUTHORIZATION

1. The existing Federal project at Plymouth Harbor was authorized by the following River and Harbor Acts and is as follows:

<u>Acts</u>	<u>Work Authorized</u>	<u>Documents</u>
March 3, 1899	Protecting by riprap the sections of Long Beach damaged by the storm of November 1898, and restoring Eel River to its former course.	Annual Report for 1899, page 1089
March 4, 1913	Dredging a channel 18 feet deep and 200 feet wide, increased at the entrance and at bends, from deep water to the town wharves, formerly in the area south of the State Pier, a distance of about 2.5 miles, with a suitable turning basin at the inner end.	House Document No. 1194, 62nd Congress, 3rd Session
September 22, 1922	Dredging a channel 150 feet wide, 15 feet deep, extending in a north-westerly direction about 0.3 mile from the present State Pier with a turning basin 300 feet square, and of the same depth, at its north-westerly end, also maintenance of the area dredged to a depth of 18 feet by the Commonwealth of Massachusetts, connecting the 15 foot channel with the 18 foot channel in the vicinity of the State Pier.	House Document No. 996, 66th Congress, 3rd Session

<u>Acts</u>	<u>Work Authorized</u>	<u>Documents</u>
October 23, 1962	Construction of a rubblestone break-water extending 1400 feet easterly from a point north of the Town Wharf, and thence southeasterly for a distance of 2,100 feet; and an anchorage 8 feet deep and 60 acres in area inside the breakwater	Senate Document No. 124, 87th Congress, 2nd Session

### STATUS OF EXISTING PROJECT

2. The existing project has been completed except for the construction of the breakwater and anchorage authorized in 1962 and described in the previous paragraph. Last maintenance work was completed in October 1964 and consisted of dredging the 18 and 15 foot channels, including the turning basin in the vicinity of the Town Wharf, to a 15 foot depth. The total cost of new work on the existing project through FY 1965 was \$322,560, including non-Federal contributions of \$108,000 while the total cost of maintenance work was \$694,848, including non-Federal contributions of \$400.

### REQUIREMENTS OF LOCAL COOPERATION

3. The uncompleted project modification was authorized in 1962 subject to the requirements that local interests agree, prior to construction, to:

a. Contribute in cash 20 percent of the first cost of construction, such contribution, then estimated at \$300,000, to be paid in a lump sum prior to initiation of construction, subject to final adjustment after annual costs have been determined; and

b. Maintain existing public landings open to all on equal terms and provide without cost to the United States all necessary mooring facilities in the anchorage; and

c. Provide without cost to the United States all lands, easements, and rights-of-way necessary for construction and subsequent maintenance of the project and of aids to navigation upon the request of the Chief of Engineers, including suitable areas determined by the Chief of Engineers to be required in the general public interest for initial and subsequent disposal of spoil and necessary retaining dikes, bulkheads, and embankments thereof or the costs of such retaining works; and

d. Hold and save the United States free from damages due to the construction and subsequent maintenance of the project.

### PREVIOUS PROJECT

4. Prior to adoption of the existing project, temporary structures were erected for the protection of Long Beach. Channel dredging to a depth of 9 feet was also effected. The work was accomplished at intervals during the period from 1824 to 1898. Total Federal expenditures under these previous projects amounted to \$190,660 of which \$188,647 was for new work while \$2,013 was for maintenance.

### INVESTIGATIONS

5. The basic data used in developing plans for the uncompleted project, authorized in 1962 and consisting of the breakwater and anchorage, is contained in a Survey Review Report of Plymouth Harbor, prepared by the Division Engineer and dated 3 August 1961. This report is contained in Senate Document No. 124, 87th Congress, 2nd Session.

6. Prior to the above a report of preliminary examination scope was submitted by the Division Engineer on 24 February 1950.

7. Additional data, obtained subsequently to the above Survey Review Report, and used in the preparation of this Design Memorandum, consist of the following:

a. Hydrographic survey made in October 1964 of the project channel and turning basin.

b. Core borings (3) made in July 1963 in the breakwater and anchorage areas.

c. Core borings (10) made in June 1964 in the breakwater and anchorage areas, one of which included undisturbed sampling by means of a 3-inch Shelby tube, of the harbor bottom material in the areas of the proposed breakwater foundation.

d. Compilation and analysis of tidal, major storms, and wind data.

### LOCAL COOPERATION

8. The requirements of local cooperation are stated in Paragraph 3.

The town of Plymouth has approved the project plan, as modified below, and has appropriated \$232,500 as their share of the present estimated cost. The Commonwealth of Massachusetts has pending legislation seeking authorization of the project plan and an appropriation of \$232,500 as their contribution. State Legislators, representing the Plymouth area, have expressed their opinions that legislation will receive favorable action by about March 1966.

9. A document letter, dated 8 June 1962, from the Assistant Secretary of the Interior to the Chief of Engineers requests that the authorized project plan be modified to provide for sport-fishing activities on the breakwater, providing subsequent studies determine that the following requested additional features would be economically feasible:

a. "That the west arm of the breakwater be terminated on shore, or a walkway from shore to the breakwater be provided.

b. That the breakwater be capped and guard rails and other features be provided to assure safe fishermen use.

c. That public access and parking facilities be provided."

The U. S. Fish and Wildlife Service has estimated a net annual sport-fishing benefit of \$30,000 if the above described breakwater design modifications are made. Based on this estimate it has been determined that the addition of these features is economically feasible. Accordingly, the authorized project plan has been modified to provide for a stone causeway, with a 7 foot top width, from the shore to the west end of the breakwater, a breakwater top width of 7 feet, capping of the breakwater and causeway with one ton stones to be laid reasonably flat and a guard rail along one side of the top of the breakwater and causeway. Adequate public access, and sanitary and parking facilities exist now, and according to town officials will be maintained at the site to provide for the needs of the estimated number of sport fishermen expected to use the breakwater. State, Town, and officials of the local office of the U. S. Fish and Wildlife Service, have approved of the above proposed design changes. The project plan has been modified accordingly.

10. Investigations made in connection with this study show that there is an existing 14-inch outfall sewer pipe, of the Town of Plymouth, discharging untreated sewage in about the center of the proposed anchorage area which would be semi-inclosed by the breakwater. It is believed that continuance of this discharge would result in an obnoxious and intolerable condition upon the completion of the breakwater construction. Mr. Sumner A. Chapman, Jr., Chairman of the Plymouth Board of Selectmen,

by letter of 21 May 1965, states that the Town plans, by July 1967, to complete the replacement of this sewer pipe by constructing a new sewer system with an outfall sewer pipe in a location as shown on Plate 1 northerly of the proposed breakwater. He further states that if the Town does not make the above described sewer changes that he is sure that the Town will extend or relocate the present sewage discharge to a location outside of the proposed anchorage and breakwater.

11. Personnel of this office, on 12 February 1965, met with Town and State officials to review the project design features. At that time, Town officials stated that there are a number of small rowboats, and motor-boats which navigate from the Town Wharf to the area north of the proposed breakwater location. They requested a navigation opening to an effective depth of mean low water be provided for these boats near the west end of the breakwater, to include a 25-foot wide horizontal clearance and a 6-foot vertical clearance above mean high water. It is believed that such an opening would also provide for a limited amount of flushing action within the anchorage. The above requested modification is believed to be warranted and the project plan has been modified to provide the navigation opening together with a timber foot bridge across the opening to accommodate sport fishermen.

12. This office is reasonably certain that local interests will furnish, not later than April 1966 the required assurances that all conditions of local cooperation with respect to the project plan, as modified above, will be met.

#### LOCATION OF PROJECT

13. Plymouth Harbor is located on the east coast of Massachusetts. It is about 45 miles south of Boston Harbor and about 15 miles north of the easterly entrance of the Cape Cod Canal. It is the most southerly of three arms of a large and partially sheltered embayment which is separated from Plymouth and Cape Cod Bays by narrow sand spits. The northeasterly arm is known as Duxbury Bay and the northwesterly arm, Kingston Bay. An outer anchorage, the "Cow Yard", is common to all three arms. The harbor is formed by Long Beach (also known as Plymouth Beach), a low narrow sand spit 1.8 miles long, generally parallel to the mainland, and about 1 mile from it. The harbor has an area of about 2,000 acres. A large part of it consists of mud flats bare at low tide. The entrance to the harbor lies at the northerly end of Long Beach. From the entrance, a channel 18 feet deep (recently maintained to only a 15-foot depth) leads across extensive flats to the State Pier. The channel then continues, at

a depth of 15 feet, to a turning basin opposite the town wharf.

14. The mean range of tide is 9.6 feet and the spring range is 11.1 feet. The locality is shown on the United States Coast and Geodetic Survey Charts Nos. 245 and 1208, and on the maps accompanying this report.

#### TRIBUTARY AREA

15. The Town of Plymouth enjoys the distinction of being the oldest continuous settlement of English speaking people in the United States. It has been a permanent community since 1620, the date of the original Pilgrim landing. As such it has become a national shrine with many thousands visiting its shores annually. These visitors come, not only by land, but also by sea, as the harbor is a favorite stopping place for the many yachts that cruise New England waters during the summer recreational season.

16. The Town itself is a medium size community, having a population of 14,445 in 1960, and a real estate valuation of \$41,825,000 in 1963. It is the natural trading center for about 45,000 people in surrounding communities. Manufacturing, once the largest source of income, has declined in recent years. The Plymouth Cordage Company located in North Plymouth is reputed to be the largest rope making concern in the world.

17. Fishing is one of the basic industries. It has shown an upward trend in recent years, increasing in volume to a point where existing harbor facilities are considered inadequate. The industry is an important source of income, employing about 300 to 500 people. Plymouth is ideally located for this industry, situated as it is near prolific fishing grounds both in Cape Cod Bay and off Cape Cod.

18. The summer vacation trade, another major source of local income, is important due to Plymouth's national prominence as an historical site. Its natural assets relative to harbor facilities, and its miles of coastline, numerous ponds and extensive woods, also contribute to its recreational value. About 20,000 families are summer residents and about 60,000 tourists visit the location each year.

19. The locality is well served by excellent highways, bus lines and by a freight line of the New York, New Haven and Hartford Railroad.



## PROJECT PLAN

20. The project plan considered most feasible and economical to accomplish the work authorized in 1962, and the additional recommended work to provide for sport fishing from the breakwater, consists of a rubble stone breakwater about 3,500 feet long, a rubble stone causeway about 360 feet long extending from the westerly end of the breakwater to the land, a guard-rail along the top of the breakwater and causeway, a navigational opening through the breakwater spanned by a foot-bridge, and a 60-acre anchorage inside the breakwater.

21. The project plan provides for the removal of the existing breakwater foundation material to elevation -5.0 (MLW datum), plus a 1-foot overdepth allowance, with replacement by gravel borrow and stone. The plan involves removal of about 50,000 cubic yards of mud and sand from the breakwater foundation and about 649,000 cubic yards from the anchorage area. In view of the odoriferous and organic nature of the bulk of the material to be removed, and the lack of suitable land areas to accommodate this type of material, it is proposed to specify removal by bucket dredging with disposal to an approved offshore dumping area.

22. It is estimated that the easterly 1,750 foot section of the breakwater will settle after construction about 1 foot and the westerly section about 6 inches, therefore, it is proposed to establish crest elevation at completion of construction of +16.0 and +15.5 for the above respective sections, to allow for such settlement. It is further estimated that during construction the westerly 1750 foot section of the breakwater foundation will settle about 6 inches and the easterly 1750 foot section will settle about 1 foot. It is further estimated that an average displacement of existing material of one foot will occur during placement of gravel in foundation. Estimated stone and gravel quantities contained in the estimate of project costs reflect the above described allowances for initial settlement and displacement. It is recommended that the contract specifications require that all stone and gravel within the breakwater foundation be placed with a bucket and not dumped, and that the placement of such material precede the placement of other breakwater stone by at least 30 feet.

23. The major element of navigation improvement of the above plan consists of providing an anchorage for the current and prospective fleets, both commercial and recreational, and protection within this anchorage and those existing anchorages in the vicinity of the State

and Town wharfs, from the severe northerly storms that occur in Plymouth Harbor. The proposed breakwater would limit wave action within the anchorage, and in the State and Town wharf areas, to waves not exceeding 1.5 feet in height, except during hurricane storms.

24. Winds emanating from the northwest clockwise through the northeast have the greatest fetch (6 statute miles) and generate the maximum wave heights in the harbor. It is estimated that 50 MPH storm winds from these directions will generate 3.5 foot high waves at the breakwater location, from an easterly direction 2.0 foot high waves, and from a southeasterly direction 1.5 foot waves. The breakwater, except during hurricane storms, will provide still water within the anchorage except when winds are from the southeast, at which time wave heights of up to 1.5 feet can be expected. Design height of the breakwater was fixed at 15.0, based on a design tide of 12.7 feet, and a design wave of 3.5 feet.

25. The size of the anchorage was designed to provide for that portion of the current and prospective fleets, both commercial and recreational, which cannot now be accommodated in the existing anchorages in the vicinity of the State and Town piers. The present local recreational fleets consists of 391 boats, including outboards, inboards, cruisers, auxiliaries, and sailboats. The local fishing fleet numbers 19 draggers and 10 lobster boats, based in the harbor. Current transient boats are equivalent to 6 boats permanently based throughout the season. Prospective additions to the fleets are estimated to include 8 draggers, 5 of which are expected to be transfers from other harbors, 5 lobster boats, 110 additional recreational craft, 14 additional transient boats, and 202 additional recreational boats due to normal growth over the project life (50 years). This will result in an aggregate number of about 765 at the end of the project life. It is estimated that the 60-acre anchorage will accommodate about 600 boats, averaging 25 feet in length and tied fore and aft on moorings, leaving about 165 boats at the present mooring and docking areas in the vicinity of the state and town wharves.

#### DEPARTURES FROM PROJECT DOCUMENT PLAN

26. Changes in the present project plan from that shown in the authorized plan consist of the following:

a. - Breakwater Foundation. - The breakwater design as shown in the authorizing document provided that the breakwater be

built on the existing ground, believed at that time to be moderately good bearing material. However, subsequent borings, taken in 1963 and 1964 and shown on the maps accompanying this report, indicate that the existing foundation materials consist generally of soft organic silt overlying medium inorganic clays and silt to the maximum explored depths of 50 feet. An 8-foot stratum of medium compact sandy gravel and gravelly sand was encountered at the location of Boring No. FD-4 at a depth of 27 to 35 feet. The soft organic silt has an average depth of about 25 feet over the easterly 1750 foot section of the structure and an average depth of about 10 feet over the westerly 1750 foot long section. A revised breakwater foundation design, therefore, has been made. The revised design provides for the removal of existing material to elevation -5.0, with replacement by a 2 foot layer of gravel borrow, then quarry-run stone. Stability studies of this proposed section have been made and the factor of safety against sheer failure of the foundation normal to the centerline is considered adequate. (See Appendix A) As a precaution against longitudinal foundation failure during construction, it is proposed to provide in the contract specifications that material below El. -1.0 be placed and not dumped and will precede placement of stone above El. -1.0 by at least 30 feet.

b. - Breakwater Crest Elevation. - A settlement analysis of the breakwater, based on the revised foundation design, has been made and it is estimated the settlement over the easterly 1750 foot portion will be in the order of 2 feet while over the westerly 1750 feet will be in the order of 1 foot, of which about 50 percent may be expected to occur during construction. It is therefore proposed, in order to maintain an ultimate design crest elevation of +15.0 MLW, that the crest of the easterly half of the breakwater on completion of construction be established at elevation +16.0 and the remainder be established at elevation +15.5 with a 100 foot transition. In addition to the above settlement it is estimated that the initial placement of foundation gravel will result in displacement of the existing material to an average 1 foot depth. Estimated stone quantities in the project cost estimate reflect the above described allowances for anticipated settlement and displacement.

c. - Breakwater Crest Width. - The breakwater crest width has been widened from 5 feet to 7 feet. This was considered necessary for two reasons, the first being that a 7-foot width is considered to be the minimum for practical and safe fishermen use. The second reason is that it is estimated that the cost of placing the breakwater stone, above the existing ground level only, with land equipment would be about \$1.00 per ton less than if placed with

waterborne equipment. This method of placing stone is estimated will result in a considerable lessened net project cost. Such a method would require a causeway about 360 feet long from the land to the westerly end of the breakwater with a width of about 22.5 feet at elevation  $\pm 10.6$  and would also require a similar breakwater width at elevation  $\pm 10.6$  for an adequate working platform for the contractor's construction operations. This width, assuming retention of 1 on 1-1/2 side slopes, would require a 7 foot wide crest.

d. Causeway. - The authorized plan has further been modified to include a stone causeway about 360 feet long extending from the land to the west end of the breakwater. This structure is necessary to provide pedestrian access to the breakwater for the sport fishermen and to provide construction facilities for the placing of breakwater stone, above the existing ground level, by land equipment.

e. Guard Rail. - A single line of guard rail along the top of the breakwater and causeway has been included in the project plan to provide for fishermen safety.

f. Navigation Opening and Pedestrian Foot-bridge. - As more fully described in Paragraph 12, the authorized plan has been modified to include a navigation opening through the breakwater with an effective existing depth to mean low water, a horizontal clearance of 25 feet and a vertical clearance above mean high water of 6.0 feet, at a location about 240 feet easterly from the west end of the breakwater. Included also is a wooden foot-bridge spanning the opening to provide pedestrian access along the breakwater for sport fishermen.

#### SHORELINE CHANGES

27. The west or mainland shore of Plymouth Harbor consists partly of narrow beaches fronting moderately steep upland, and partly of marsh areas. In the vicinity of the authorized improvement, the shore is developed and protected by seawalls, riprap, and bulkheads. The shore appears to be stable and, therefore, it is considered that the proposed improvement would not contribute to any significant erosion of this shore. The harbor bottom is composed mainly of mud flats, the major portion of which are above the plane of mean low water. No appreciable change has occurred in the elevation of these flats since 1910, as evidenced by a comparison of a Corps of Engineer's survey of that year with the latest U. S. Coast and Geodetic Survey Chart. In view of the small amount of littoral movement of materials, it is considered that the shoaling of the anchorage and adjacent channels will be minor.

## COST ESTIMATES

28. Quantities have been estimated on the basis of the 1959 survey and on the structure dimensions shown on the accompanying plates. Dredging quantities within the anchorage and breakwater areas include an allowance of one foot for over-dredging. Stone quantities are based on an estimated one foot settlement of the causeway and breakwater foundation stone during construction and an additional estimated one foot displacement of the existing material under the breakwater during initial placement of gravel. Stone quantities are further based on lean dimensions, to the prescribed structure limits, and on in-place weight of 1.65 tons per cubic yard for placed armor stone and on 1.5 tons per cubic yard for all other type stone.

29. The estimate of cost for accomplishment of the authorized project, as modified, is based on unit prices prevailing in February 1966, on dredging by bucket method with disposal at sea, on placement of breakwater foundation stone and gravel by waterborne equipment, and on placement of all other stone by land equipment. The following estimates show the first cost of construction for the complete project plan, including the added features considered necessary to provide for a recreational development consisting of breakwater use for sport fishing, and also the first cost of construction for only the added recreational development features.

First Cost of Construction

Complete Project Plan (Incl. Recreat.  
Development Features)

Recreat. Dev. Feat. Only  
(see Appendix B)

Dredging

Within anchorage area  
649,000 c. y. x \$1.05 \$682,000  
Within breakwater area  
50,000 c. y. x \$1.05 52,500

734,500

Stone Furnished & Placed

In breakwater  
181,300 ton x \$5.60 1,015,300  
In causeway  
9,500 ton x \$5.20 49,400

Gravel Borrow Furn. & Placed

In brkwr found. 28,500 ton x \$2.80 79,800

Guard Rail

3800 l. f. x \$2.00 7,600

Foot-bridge

l. s. 6,500

\$1,893,100

Contingencies (12%) 227,100

Total Contract Cost

\$2,120,200

1300 ton x \$5.60 \$ 6,800

1400 ton x \$5.20 7,300

3800 l. f. x \$2.00 7,600

l. s. 6,500

\$28,700

3,400

say \$32,100

First Cost of Construction (Cont'd)

<u>Complete Project Plan (Incl. Recreat. Development Features)</u>		<u>Recreat. Dev. Feat. Only (see Appendix B)</u>
Total Contract Cost	\$2,120,200	say \$32,100
Engineering & Design	65,000	1,000
Supervision & Administration	<u>140,000</u>	<u>2,000</u>
Total Project Construction Cost	\$2,325,200	
(C of E Funds & Non-Fed. Contribution)	say 2,325,000	35,000
Aids to Navigation (Coast Guard)	1,000	- - - -
Estim. value of locally furnished basic facilities for recreational development (see App. B)	<u>20,000</u>	<u>20,000</u>
Total Project Cost (Fed. Funds & Non.-Fed. Contribution)	\$2,346,000 <sup>(1)</sup>	\$55,000

(1) Exclusive of \$10,000 Preauthorization Studies

## COMPARISON OF COSTS

30.	<u>Document Estimate</u> Oct. 1962.	<u>Latest Approved Estimate</u> Jan. 1966	<u>Current Estimate</u> Feb. 1966
Rubble Stone Breakwater (incl. contingencies)	610,000	1,250,000	1,297,000 <sup>(1)</sup>
Breakwater Found. Dredging (incl. contingencies)	- - - - -	60,000	59,000
Basin Dredging (incl. con- tingencies)	784,000	810,000	764,000
Preauthorization Studies	10,000	deleted	deleted
Engineering & Design	20,000	65,000	65,000
Supervision & Administration	<u>86,000</u>	<u>140,000</u>	<u>140,000</u>
Totals	1,510,000 <sup>(2)</sup>	2,325,000 <sup>(2)(3)</sup>	2,325,000 <sup>(2)(3)</sup>

(1) Includes construction costs of breakwater extension to shore, guard rail, and foot-bridge.

(2) Excludes \$1,000 Aids to Navigation

(3) Excludes \$20,000, estimated value of basic facilities for recreational development, e. g., access lands, parking and sanitary facilities.

### 31. Allocation of Costs

#### Federal

Corps of Engrs.	1,200,000	1,860,000	1,860,000
Coast Guard (Aids to Nav.)	- - - - -	- - 1,000	1,000
Total Federal	<u>1,200,000</u>	<u>1,861,000</u>	<u>1,861,000</u>

#### Non-Federal

20% of Total Constr. Costs	300,000	465,000	465,000
Est. value of basic facilities for recreational development, e. g., access lands, parking and sanitary facilities	- - - - -	20,000	20,000
Total Non-Federal	<u>300,000</u>	<u>485,000</u>	<u>485,000</u>
Total Fed. & Non-Fed.	\$1,500,000	\$2,346,000	\$2,346,000



## SCHEDULE FOR DESIGN AND CONSTRUCTION

32. The improvement of Plymouth Harbor, as authorized by the River and Harbor Act of 23 October 1962, with minor modifications as described and recommended in this report, will be undertaken under two contracts. The first contract will include the dredging of the anchorage basin and the breakwater foundation. The second contract will include the breakwater construction, including its extension to the shore, installation of guard-rail on the breakwater, and the construction of a foot-bridge spanning the navigation opening through the breakwater. Local interests do not object to construction work during the summer months. Present project schedule, contingent on appropriations and local cooperation (including removal of sewerage discharge in anchorage area) is as follows:

	<u>Dredging Anchorage &amp; Breakwater Foundation</u>	<u>Breakwater Construction</u>
Issue Plans & Specifications	25 April 1966	21 Oct. 1966
Open Bids	25 May 1966	23 Nov. 1966
Start Construction	5 July 1966	3 Jan. 1967
Complete Construction	31 March 1967	30 Jun 1968

33. Fund requirements for the above schedule is as follows:

Allotted to date	\$ 335,000
Fiscal Year 1967	765,000
Fiscal Year 1968	<u>760,000</u>
Total Funds	\$1,860,000

## OPERATION AND MAINTENANCE

34. Maintenance of the authorized navigation improvement, providing for an anchorage and breakwater, and including the breakwater extension to the shore, is the responsibility of the United States, and will consist of periodic dredging in the anchorage to restore project depths, and repairs to the breakwater, guard-rail and foot-bridge. Anchorage shoaling is expected to be at the rate of about 7,000 cubic yards per year and its annual maintenance cost is estimated at \$10,000. Annual maintenance costs of the breakwater is estimated

at \$8,000, of the guard-rail \$1,000, and of the foot-bridge \$1,000. Maintenance and operation of the recreational development features of the project, to provide for sport fishing from the breakwater, e.g., access, parking and sanitary facilities, is the responsibility of non-Federal interests (State and/or Town). Annual maintenance and operational costs of these facilities is estimated to be \$5,000, however, it is expected that local interests will charge a nominal fee for use of these facilities and thus place these costs on a self-liquidating basis. Annual maintenance costs of the navigation aids is estimated at \$160.

### BENEFITS

35. The benefits expected to accrue from improvement of Plymouth Harbor by provision of a protected anchorage, including recreational development features to provide for sport fishing from the breakwater, will be in part general and in part local. General benefits will accrue from reduction in storm damage to commercial fishing vessels and additions to the fishing fleet both in new boats and in transfers from other harbors. Recreational benefits which are equally general and local, will result from elimination of storm damage to recreational craft, increased use of the harbor by the present local and transient fleets, and by additions to those fleets as a result of the improvement. Additional recreational benefits will result from use of the breakwater by sport fishermen. In addition, certain area redevelopment benefits will result.

36. The estimate of project benefits were evaluated and described in detail in the Survey Report dated 3 August 1961, subsequently incorporated in the authorizing document. These benefits have been re-evaluated, in view of increased cost and price levels since that date, and are as follows:

<u>Revised Fishing Benefits</u>	<u>Revised Annual Benefits</u>
a. - Increased fish catch (3 new draggers). Ex-vessel price of \$0.056 per pound was that prevailing in 1957. Current price is about 10% higher.	
$1,875,000 \# \times \$0.062 \times .40^{(1)}$	\$46,500
(1) Net Value = 40 percent of gross value	
b. - Saving in Trucking Charges (from 5 transferred draggers. Current trucking charges have increased since 1961 by about 10%, therefore	

Revised Fishing Benefits (Cont'd)Revised Annual  
Benefits

savings in these trucking charges will increase at about same rate. Since average annual catch of each boat is 625,000 pounds, the total annual catch for 5 transferred draggers would be  $5 \times 625,000$  or 3,125,000 pounds. At \$0.63 per 125 pounds saving in trucking charges, the saving would amount to

$$\frac{\$0.63 \times 3,125,000^\#}{125^\#} \qquad \$ 15,700$$

c. - Reduction in fishing boat damage - no change 6,000

d. - Increased lobster catch - new lobster boats (5).  
Current ex-vessel price is about 10% higher than in 1961.

$$12,500^\# \times 5 \times \$0.55 \times .40^{(1)}$$

(1) Net value = 40% gross value 13,750

sub-total \$ 81,950

Revised Benefits - Recreational Fleet

e. - It is estimated that the average value of recreational craft has increased by about 10% since 1961. The following revised estimated annual benefits reflect this increase.

Local recreational fleet-increased use plus gradual growth	
$\$24,600 \times 1.10$	\$ 27,100
New recreational boats $\$11,600 \times 1.10$	12,800
Present and anticipated transient recreational boats	
$\$ 4,800 \times 1.10$	5,300
Reduction in recreational boat damage-no change	<u>6,000</u>
	51,200
Total	\$132,850

37. The U. S. Fish and Wildlife Service has estimated that the project plan, which includes features to provide for sport fishing from the breakwater, will result in an annual 20,000 fishermen-day use, with a resultant annual sport fishing benefit of \$30,000.

38. It is expected that certain additional benefits will result from project construction in the nature of employment of local labor.

*Total  
2530 from fish*

The Town of Plymouth, together with the neighboring towns of Kingston and Plympton, has been classified as a redevelopment area by the Area Redevelopment Administration under Section 5B of Public Law 87-27, and therefore the project, by employing local labor which is unemployed or under-employed, is entitled to redevelopment benefits. Such benefits have been derived based on the estimated labor cost of the work with appropriate allowances made for the proportion of labor which is expected will be hired locally and the number of those hired who would otherwise be unemployed or under-employed. Benefits so derived amount to \$150,000. Expressed as an annual equivalent benefit this amounts to \$5,700.

39. The following table shows a summary of the annual benefits expected to accrue from the project.

TABLE I  
SUMMATION OF ESTIMATED ANNUAL BENEFITS

<u>Source</u>	<u>General</u>	<u>Local</u>	<u>Total</u>
<u>Fishing Industry</u>			
Increased Fish Catch (3 new draggers)	46,500	-	\$ 46,500
Saving in Trucking Charges (5 transferred draggers)	15,700	-	15,700
Reduction in Boat Damage	6,000	-	6,000
Increased Lobster Catch (5 new boats)	13,750	-	13,750
<u>Recreational Boats</u>			
Local Fleet (increased use, gradual growth)	13,550	13,550	27,100
New Boats (110)	6,400	6,400	12,800
Present & Anticipated Transient Boats	2,650	2,650	5,300
Reduction in Boat Damage	3,000	3,000	6,000
<u>Recreational Development</u>			
Sport Fishing	15,000	15,000	30,000
Sub-total	\$122,550	\$40,600	\$163,150
Percentage	(75)	(25)	(100)
Redevelopment Benefits	-	-	5,700
		Total	\$168,850

## ANNUAL CHARGES

40. Annual charges are based on a project life of 50 years with an interest rate of 3-1/8% per annum. Estimates of maintenance represents the expected requirements during that period, expressed in terms of the annual average. The computation of annual charges is tabulated below:

### Federal

#### Corps of Engineers

Interest & Amortization (1,860,000 x .03979)	\$74,000	
Maintenance		
To breakwater	8,000	
To foot-bridge	1,000	
To guard-rail	1,000	
Anchorage Dredging	<u>10,000</u>	
	<u>20,000</u>	
		\$94,000

#### U.S. Coast Guard

Interest & Amortization (1,000 x .03979)	40	
Maintenance - Aids to Nav.	<u>160</u>	
		<u>200</u>

Total Federal      \$94,200

### Non-Federal

Interest & Amortization (485,500 x .03979)	<u>\$19,300</u>	
Total Non-Federal		<u>19,300</u>

Total Annual Charges      \$113,500

## BENEFIT-COST RATIO

41. The benefit-cost ratio of the complete project plan, including the recreational development features, and the benefit-cost ratio of only the recreational development features of this plan, are tabulated below:

	<u>Annual Charges</u>	<u>Annual Benefits</u>	<u>B/C Ratio</u>
Recreational develop- ment features only	4,200	30,000	7.1
<u>Project Plan -w/o recreat.</u> devel. features			
Incl. redevelopment benefits	112,400	138,850	1.2
W/O redevelopment benefits	112,400	133,150	1.1
<u>Project Plan - with</u> recreat. devel. features			
Inc. redevelopment benefits	116,600	168,850	1.4
W/O redevelopment benefits	116,600	163,150	1.4

### RECOMMENDATIONS

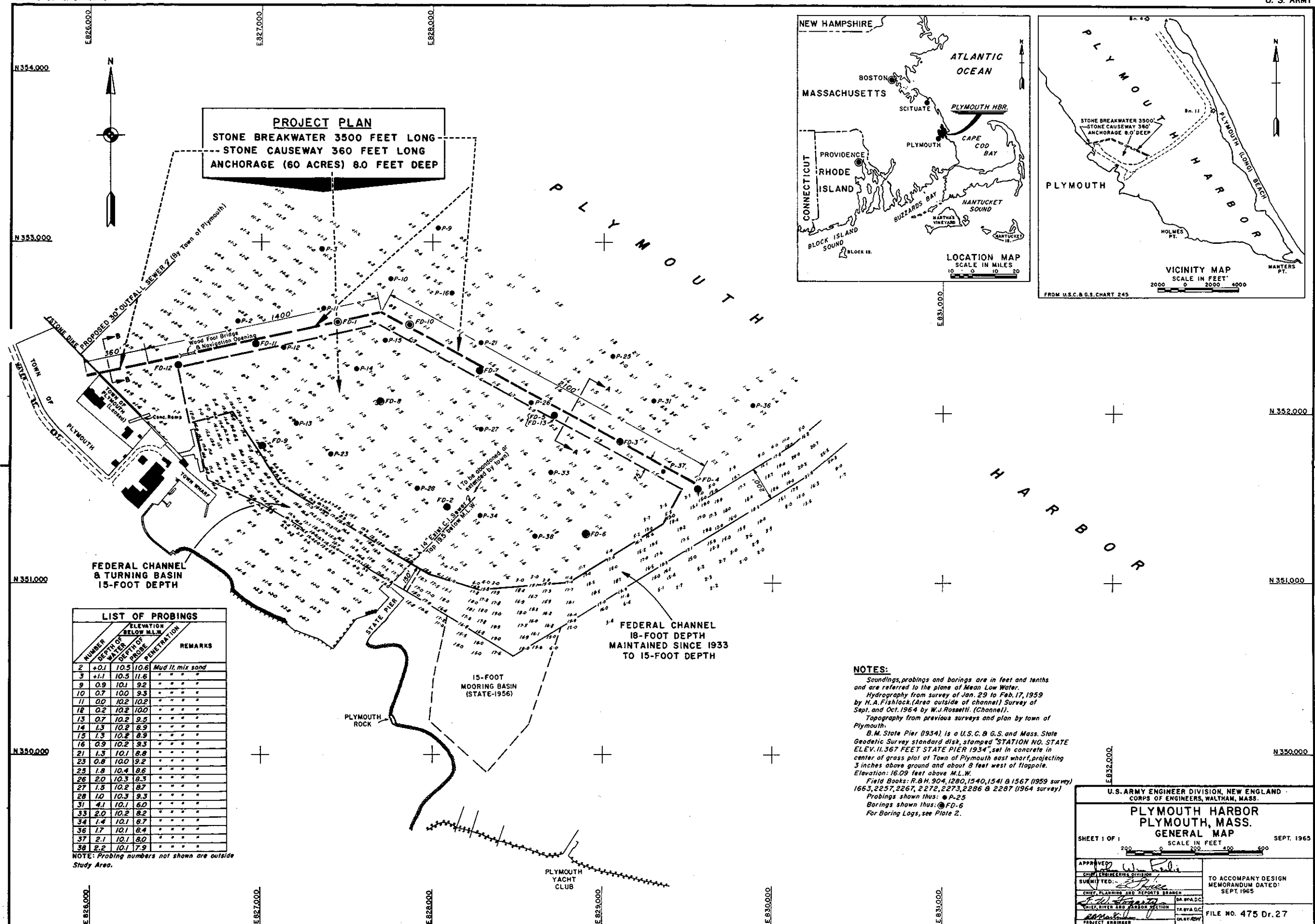
42. The plan of improvement proposed in this design memorandum provides for a rubble stone breakwater about 3500 feet long, a rubble stone causeway about 360 feet long extending from the westerly end of the breakwater to the land, a guard-rail along the top of the breakwater and causeway, a navigation opening through the breakwater spanned by a foot-bridge, and a 60-acre anchorage 8 feet deep inside the breakwater. The plan is essentially the same as that described in Senate Document No. 124, 87th Congress, 2nd Session, and authorized by the River and Harbor Act of 23 October 1962, except that the causeway, guard-rail and foot-bridge have been added to provide a recreational development for sport fishing from the breakwater.

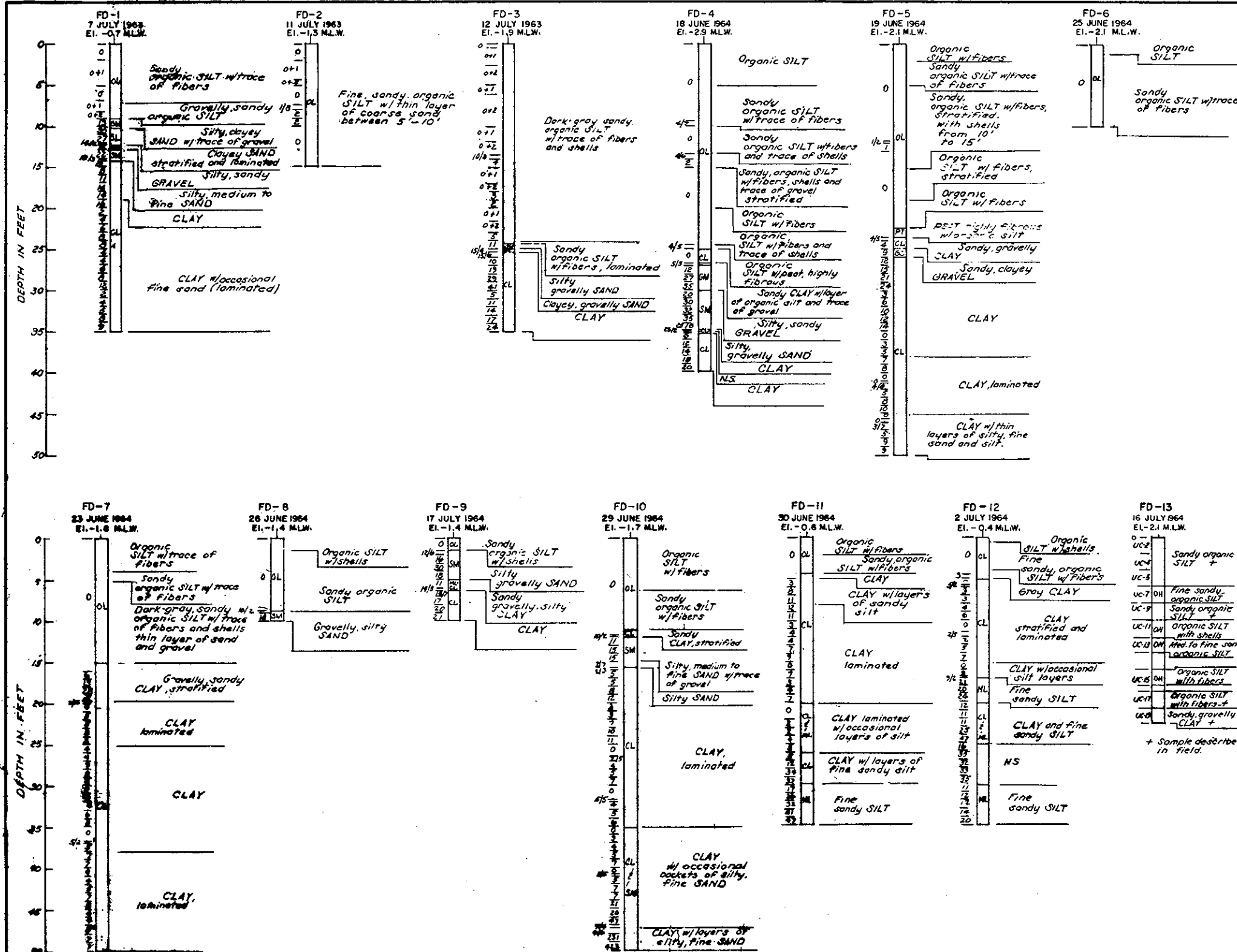
43. This project plan will serve adequately the needs of present and prospective navigation in Plymouth Harbor and is economically justified. It is recommended that the project be constructed as described.

15 Incls

11 Plates

Appendices A, B, C, & D





## LEGEND FOR GRAPHIC LOGS

FD	Test Boring
11 JULY 1964	Date exploration completed
El. -1.3 MLW.	Elevation of ground surface during time of exploration
OL	Group letter symbol according to Unified Soil Classification System
NS	Not Sampled Hole advanced by Core-drilling blasting and/or wash boring due to operational difficulty
35	Number of blows per foot of penetration using a 350 lb. hammer falling freely about 18 inches on a 2" or 2 1/2" I.D. sample spoon equipped with a beveled and sharpened drive shoe. Fractional foot of penetration indicated as follows: number of blows/tenths of a foot (15/4)
0+2	In loose or soft overburden sampling spoon may be advanced as follows: 0 Weight of tools 0+1 Weight of tools plus one man 0+2 Weight of tools plus two men
UCI 1/2	Designation and depth range of 3" Shelby Tube Sample

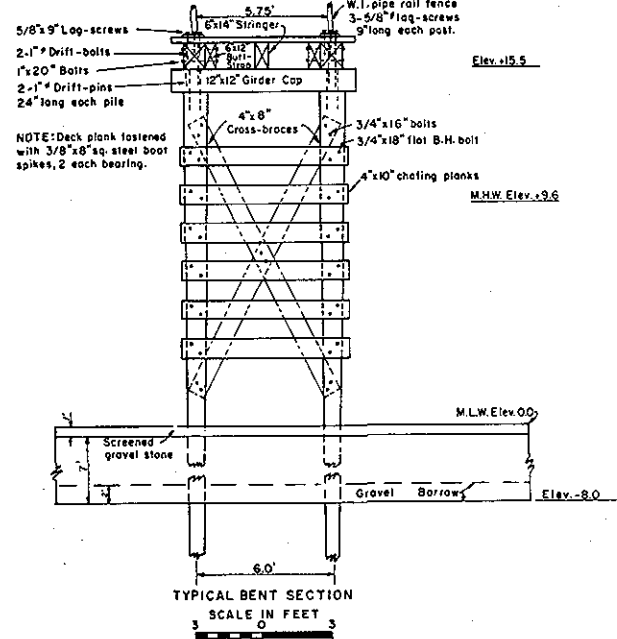
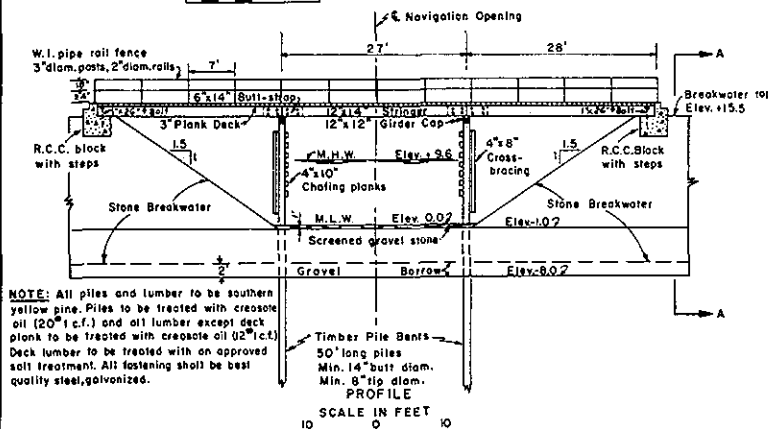
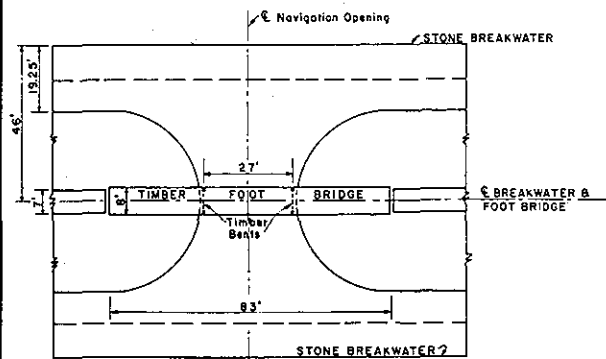
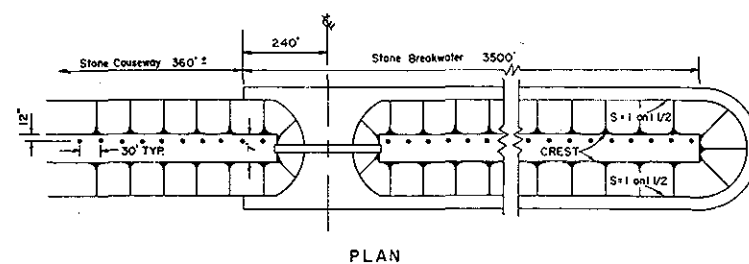
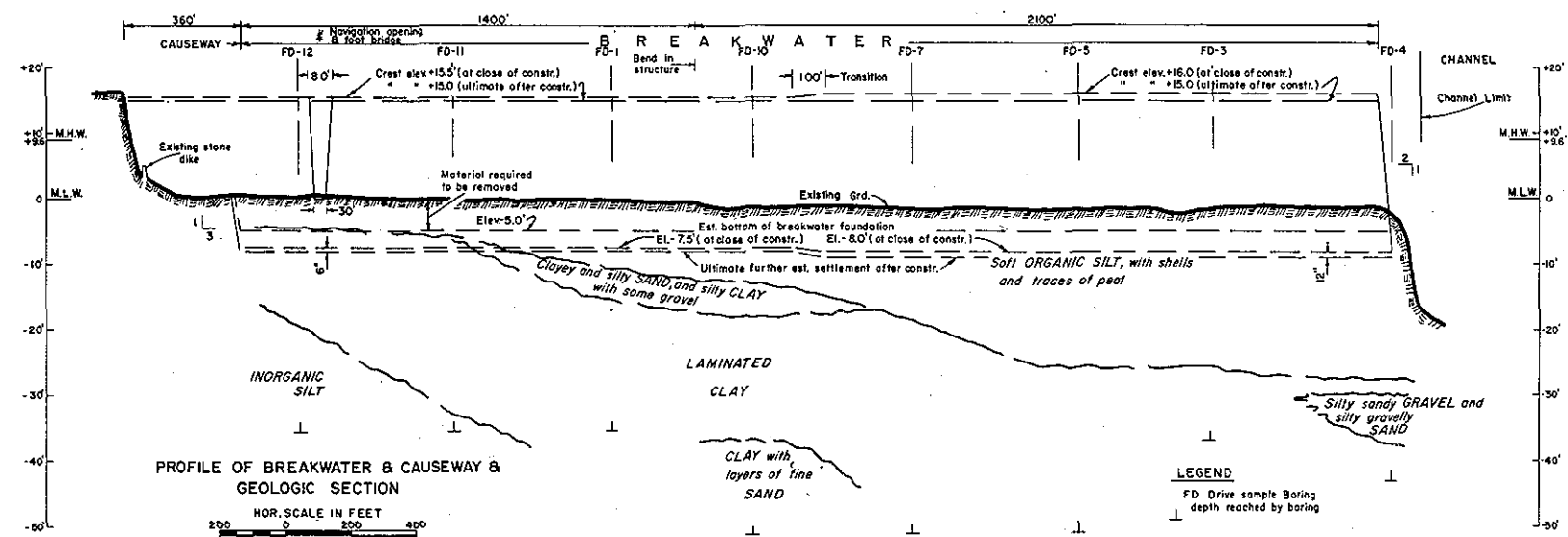
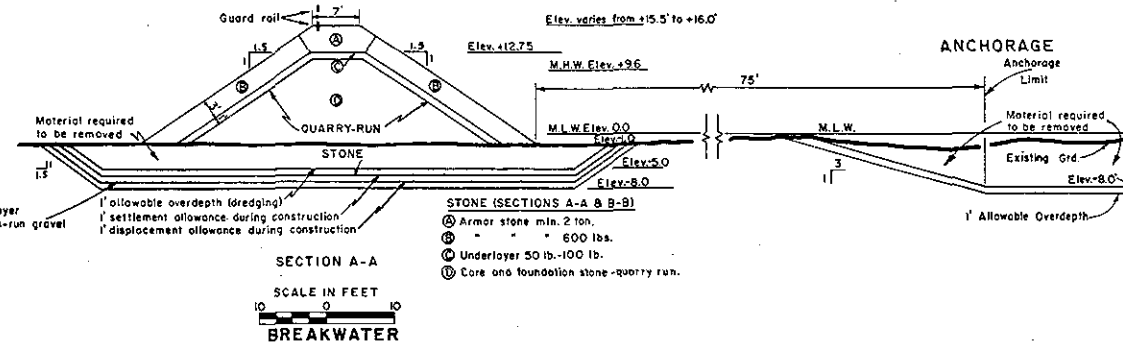
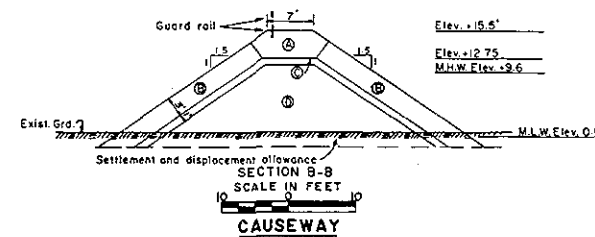
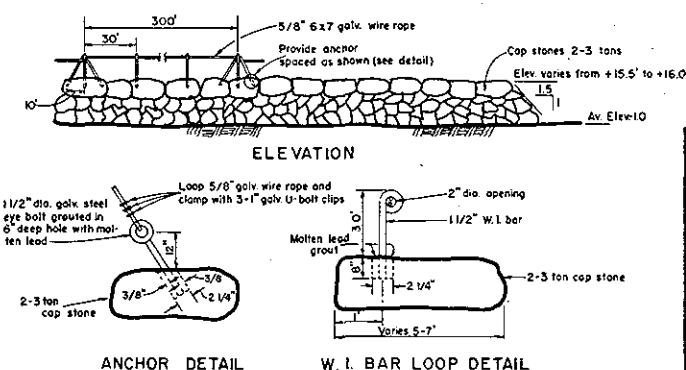
NOTES:  
Penetration resistance of sampling spoon increases with length of drive, and blow counts, therefore, generally increase correspondingly except where distinct changes in material occur within the length of drive. In gravel, sand and gravel and some glacial fills, the presence of coarse gravel, boulders or boulders causes the blow count to become erratic and, therefore, may not be indicative of the degree of compaction.

While the explorations are representative of subsurface conditions at their respective locations and for their respective vertical reaches, local variations characteristic of the overburden and rocks of this region are anticipated and if encountered, such variations will not be considered as differing materially from represented conditions within the purview of Article 4 of the Contract.

FD-13 undisturbed boring using 3" Shelby sampling tube

REVISION		DATE		DESCRIPTION	
U.S. ARMY ENGINEERING DISTRICT, NEW ENGLAND					
PLYMOUTH HARBOR PLYMOUTH, MASS. RECORD OF EXPLORATIONS					
SHEET 1 OF 1				SEPT. 1965	
TO ACCOMPANY DESIGN MEMORANDUM DATED: SEPT. 1965				DESIGN NUMBER 476 Dr.27	

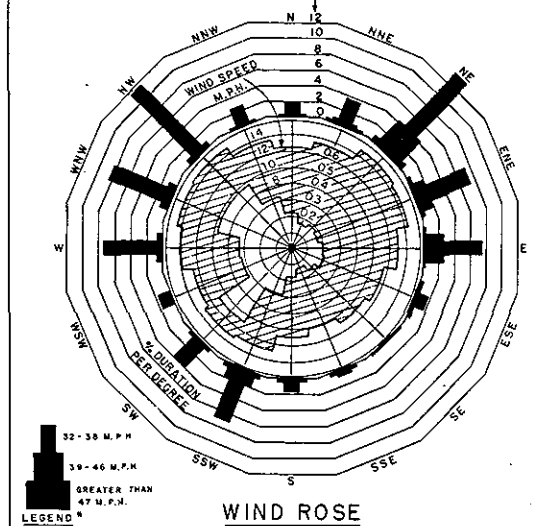


BREAKWATER-TIMBER FOOT BRIDGE  
SPANNING NAVIGATION OPENINGGUARD RAIL DETAILS  
NOT TO SCALE

ANCHOR DETAIL

W.I. BAR LOOP DETAIL

\*DURATION FOR EACH RANGE OF WIND SPEEDS IS MEASURED OUTWARD FROM TOP OF UNDERLYING BAR GRAPH.  
NOTE:  
PERCENT DURATION PER DEGREE IS THE AVERAGE PERCENT DURATION OBSERVED FOR EACH 16 POINTS OF THE COMPASS DIVIDED BY 22-1/2 DEGREES.

LOGAN AIRPORT, BOSTON, MASS.  
OCTOBER 1949 - SEPTEMBER 1959  
10 YEAR RECORD

NOTE:  
Plan revised Feb. 1966

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND  
CORPS OF ENGINEERS, WALTHAM, MASS.

PLYMOUTH HARBOR  
PLYMOUTH, MASS.

STRUCTURAL DETAILS, GEOLOGIC SECTIONS  
AND WIND ROSE  
SCALE AS SHOWN

APPROVED: [Signature]  
SUBMITTED: [Signature]  
CHIEF, PLANNING AND REPORTS BRANCH  
CHIEF, DESIGN AND CONSTRUCTION BRANCH  
CHIEF, CIVIL ENGINEERING SECTION  
PROJECT ENGINEER

TO ACCOMPANY DESIGN  
MEMORANDUM DATED:  
SEPT. 1965

FILE NO. 477 - Dr. 27

DESIGN MEMORANDUM  
ON  
PLYMOUTH HARBOR, MASS.  
INDEX - APPENDICES

APPENDIX A

Design Factors & Analysis

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6.	Prevailing Winds	A-3
7.	Winds Affecting Project Site	A-3
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APPENDIX B - Proposed Recreational Development-Sport  
Fishing from Breakwater B-1-B-5

APPENDIX C - Analysis of Project Plan-Based on a 100-Year  
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APPENDIX D - Letters of Local Interests on Recreational  
Development (Sport Fishing from Breakwater)  
Letter dated 22 Sept. 1965 from Town of Plymouth  
Letter dated 3 March 1965 from Mass. Dept. of  
Public Works

DESIGN MEMORANDUM  
ON  
PLYMOUTH HARBOR, MASS.  
APPENDIX A  
DESIGN FACTORS & ANALYSIS

1. Statement of the Problem. - The principal difficulties attending navigation in Plymouth Harbor stem from the exposed condition of the harbor and the lack of adequate protected anchorage for the fishing and recreational fleets, both present and prospective.

2. Design Criteria. - Proposed navigational improvements, consisting of a breakwater about 3500 feet long and containing a limited navigation opening as requested by local interests, and a 60-acre anchorage, are designed to provide a protected anchorage, limited to 1-1/2 foot waves, sufficient to accommodate the present and prospective fishing and recreational fleets. At the request of the U. S. Fish & Wildlife Service, and with the approval of local interests (see Appendix B), the project plan has been modified to include recreational development features to provide for sport fishing from the breakwater. These features consist of a 360-foot long causeway to the breakwater, a foot-bridge spanning the navigation opening through the breakwater, guard-rail along the tops of the structures, and off-site access, sanitation and parking facilities.

3. Tides. - Tides in the project are semi-diurnal. Mean and spring tidal ranges in Plymouth Harbor vary from 9.6 feet to 11.1 feet, respectively, and are considered to be directly proportional and about 0.1 feet higher than those in Boston Harbor.

4. Tidal Observations. - Tidal observation records made at the nearest U. S. Coast & Geodetic Station, located at Commonwealth Pier in Boston Harbor, a distance of about 45 miles from Plymouth Harbor, from 1921 to 1952, indicate the highest tide during this period was 13.8 feet. The frequency of tides exceeding mean high water by 2.0 feet or more during this 30-year period is summarized below:

TABLE A-1

Number of Tides, at Boston Harbor, Exceeding Mean High Water by  
2.0 Feet or More during Period August 1921 - March 1952

<u>Feet</u> <u>Above MHW</u>	<u>No. of</u> <u>Occurrences (Accumulative)</u>	<u>Average No. of</u> <u>Occurrences Per Year</u>
4.3	1	0.03
4.2	2	0.06
4.1	2	0.06
4.0	2	0.06
3.9	2	0.06
3.8	2	0.06
3.7	3	0.1
3.6	4	0.1
3.5	5	0.2
3.4	7	0.2
3.3	14	0.5
3.2	21	0.7
3.1	32	1.1
3.0	44	1.5
2.9	67	2.2
2.8	83	2.7
2.7	110	3.6
2.6	144	4.8
2.5	205	6.8
2.4	277	9.1
2.3	358	11.8
2.2	463	15.3
2.1	560	18.5
2.0	741	24.5

Based on these records, it is determined that the design tide at Plymouth Harbor for a frequency of once a year would be 3.1 feet <sup>1</sup>/<sub>4</sub> above mean high water or Elevation +12.7 (mean low water datum).

5. Tidal Currents. - Tidal currents in Plymouth Harbor, at a location about 4000 feet northeasterly of the project site, as given by the U. S. Coast & Geodetic Survey "Tidal Current Tables for 1965, Atlantic Coast of North America", are as follows:

Position:	Plymouth Hbr.	Lat. 41° -58', Long. 70° -39'
Current Flood:	Average 0.5 knots	Direction: 245° (True)
	Max. 66 knots	
Current Ebb:	Average 0.4 knots	Direction: 10° (True)
	Max. .60 knots	

6. Prevailing Winds. - United States Weather Bureau wind records at Boston, the weather station located about 45 miles and nearest the project site, were obtained from Oct. 1949 to Sept. 1959, a 10-year period. A wind rose based on these observations is shown on Plate 3 and a tabulation showing wind speeds and directions is shown in Table A-2, on the next page.

7. It is considered that winds prevailing at Plymouth Harbor are similar to those at Boston Harbor. The above records indicate that the prevailing winds are from a westerly direction with the greatest duration from the southwest. Inasmuch as the project area faces open water only from the northwest clockwise through the southeast, the wave action affecting the area must be generated by winds from these directions. The wind frequency for all winds and for duration of hours of winds over 32 m.p.h., for this 10-year periods, for winds affecting the area, are as follows:

Percentage of Frequencies of All Winds (1949-1959)

Direction	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	Total
Percentage	11	7	5	3	4	4	5	5	4	48

Duration of Hours of Winds Greater than 32 MPH (1949-1959)

Direction	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	Total
32-38 mph	109	23	15	31	87	55	50	14	-	384
39-46 "	7	4	3	5	32	16	22	-	-	89
47 mps & over	4	-	-	1	11	4	2	4	1	27
Totals	120	27	18	37	130	75	74	18	1	500

The predominant wind-generated waves affecting the project site will be from the northwest clockwise through the northeast, amounting to approximately 42 percent of the total hours of duration for all winds exceeding 32 mph. Fetch distances to the project site from these directions vary from 4 to 6 statute miles. The winds from the ENE clockwise through the SE account for approximately 21 percent of the total hours of duration for all winds exceeding 32 mph., but waves

TABLE A-2  
WIND SPEEDS AND DIRECTIONS (OCTOBER 1949 - SEPTEMBER 1959 INCLUSIVE)  
BOSTON, MASSACHUSETTS  
NUMBER OF HOURS

Wind Speed M. P. H.	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 & Over	Total	% Total Duration	Average Speed MPH	Wind Movement Miles	% Total Movement	% Duration per Degree
<u>Direction</u>															
N	124	703	1,681	1,344	380	125	15	3	-	4,375	5.0	12.2	53,481	4.6	0.22
NNE	92	438	985	832	382	166	31	5	1	2,932	3.3	13.4	39,356	3.4	0.15
NE	117	553	1,068	1,056	533	235	87	32	11	3,692	4.2	14.4	53,268	4.6	0.19
ENE	120	512	908	1,027	459	219	55	16	4	3,320	3.8	14.1	46,825	4.0	0.17
E	137	537	1,376	1,321	383	140	50	22	2	3,968	4.5	13.0	51,756	4.5	0.20
ESE	136	631	1,616	1,396	268	68	14	-	4	4,133	4.7	11.6	48,134	4.2	0.21
SE	124	636	1,370	974	135	26	-	-	1	3,266	3.7	11.0	35,797	3.1	0.16
SSE	98	618	1,150	508	93	27	3	2	1	2,500	2.9	10.3	25,646	2.2	0.13
S	128	912	1,591	958	251	62	13	3	-	3,918	4.5	11.0	42,967	3.7	0.20
SSW	122	905	2,081	1,911	691	217	48	16	3	5,994	6.8	13.1	78,554	6.8	0.30
SW	118	1,061	4,098	4,357	1,188	278	35	4	-	11,139	12.7	13.2	147,485	12.8	0.56
WSW	96	686	2,259	2,329	557	103	17	1	-	6,048	6.9	12.7	76,984	6.7	0.31
W	89	695	2,162	2,361	891	274	69	6	-	6,547	7.5	14.0	91,469	7.9	0.33
WNW	93	929	3,017	3,406	1,491	564	71	11	-	9,582	10.9	14.5	138,485	12.0	0.48
NW	102	845	2,587	3,479	1,558	635	109	7	4	9,326	10.7	15.0	140,066	12.1	0.48
NNW	94	633	2,011	2,418	902	203	23	4	-	6,286	7.2	13.7	86,274	7.4	0.32
Calms										606	0.7				
Totals	1,790	11,294	29,960	29,677	10,162	3,342	640	132	31	87,632	100.0	13.0	1,156,547	100.0	

generated by these winds have a limited fetch of 1 to 1.5 statute miles, due to the protection afforded by Plymouth (Long) Beach.

### BREAKWATER DESIGN ANALYSIS

8. Design Tide. - The design tide is the highest tide which it is estimated occurs in the project area on an average of once a year. The design tide of 3.1 feet above mean high water or 12.7 feet above mean low water was estimated from a 10-year period of tide records at Boston Harbor (see Table A-1, page A-2).

9. Design Wave. - The height of design wave used is the highest wave which could be expected to occur at the breakwater at the time of design tide. Determination was based on the limitations imposed by fetch and by wind speeds. The breakwater's principal exposure is to storm waves generated by winds from the NW through the NE. Of such winds those from a N and NNE direction, with a fetch of 6.0 statute miles across Plymouth Harbor and Duxbury Bay, would create the highest wave at the breakwater. This condition would probably occur during a period of sustained winds of 50 mph (statute miles) from a NNE direction. Wave generation across shallow water, with an average mean depth of 12 feet across the fetch field, based on the above conditions, is estimated to result in a wave height of 3.5 feet and a wave period of 3.3 seconds.

10. Weights and Slopes of Stone in Breakwater. - The minimum weights of armor stone have been determined from the Waterways Experimental Station formula

$$W = \frac{W_r H^3}{K_d (S_r - 1)^3 \cot \alpha}$$

where

W = weight of armor stone in pounds

W<sub>r</sub> = unit weight of stone in pounds/cu. ft.

K<sub>d</sub> = a dimensionless experimental coefficient

H = design wave height

S<sub>r</sub> = specific gravity of stone  $\frac{W_r}{W_w} = \frac{\text{unit weight stone}}{\text{unit weight of water}}$

$\alpha$  = angle of slope to the horizontal

Slopes of 1 on 1.5 have been selected as being the most economical. It is assumed that stone will be obtained from commercial quarries in the Towns of Weymouth and Hingham, a distance of about 25 miles from the project site. Stone from this source is granite, weighing 164 pounds

per cubic foot. The breakwater design is based on the use of rough armor stone, placed, and two stones thick. Due to poor soil foundation conditions it is estimated that the breakwater will settle, both during and after construction, in the order of 1 to 2 feet. This settlement is expected will result in a general loosening of the armor stone after placement, therefore a  $K_d$  coefficient of 2.0, rather than a higher one, has been used. The minimum weight of armor slope stone, based on 1 on 1.5 slopes, stone unit weight of 164 lbs./cu. ft., and a  $K_d$  coefficient of 2.0, results in a stone weighing 616 pounds, say 600 pounds. Based on an assumption that the stones are cubical in shape, the stones would measure 1.54 feet on a side. The thickness, therefore, of the slope armor stone, based on a two stone thick layer, is 3.08 ft., say 3.0 feet. The underlayer stone, 1 foot thick, was designed to contain assorted sizes, with the minimum to be about 10 percent the weight of minimum armor stone, say 50 to 100 pounds. The core and foundation stone will be quarry-run. The size and minimum weight of the crest armor stones were designed to provide a reasonably safe walkway for sport fishermen and require a minimum size stone weighing not less than 4000 pounds.

11. Crest Width and Elevation. - The top width of the breakwater was designed at 7.0 feet to provide safe and adequate facilities for sport fishermen. Wave run-up was computed for the breakwater using the composite method. Run-up was determined at 2.0 feet which superimposed on the design tide of 12.7 feet results in a top elevation of run-up of 14.7. The breakwater crest was therefore established at El. 15.0, however, a settlement analysis of the breakwater has been made and it is estimated the settlement over the easterly 1750 foot portion will be in the order of 2 feet and over the westerly 1750 foot portion will be in the order of 1 foot, of which about 50 percent may be expected to occur during construction. It is therefore proposed, in order to maintain an ultimate design crest elevation of 15.0, that the crest of the easterly half of the breakwater on completion of construction be established at El. 16.0 and the remainder be established at El. 15.5, with a 100-foot intervening transition.

12. Breakwater Foundation. - The breakwater design as shown in the authorizing document provided that the breakwater be built on the existing ground, believed at that time to be moderately good bearing material. However, subsequent borings, taken in 1963 and 1964 and shown on Plate 2, show that the existing foundation materials consist generally of soft organic silt overlying medium inorganic clays and silt to the maximum explored depths of 50 feet. An 8-foot stratum of



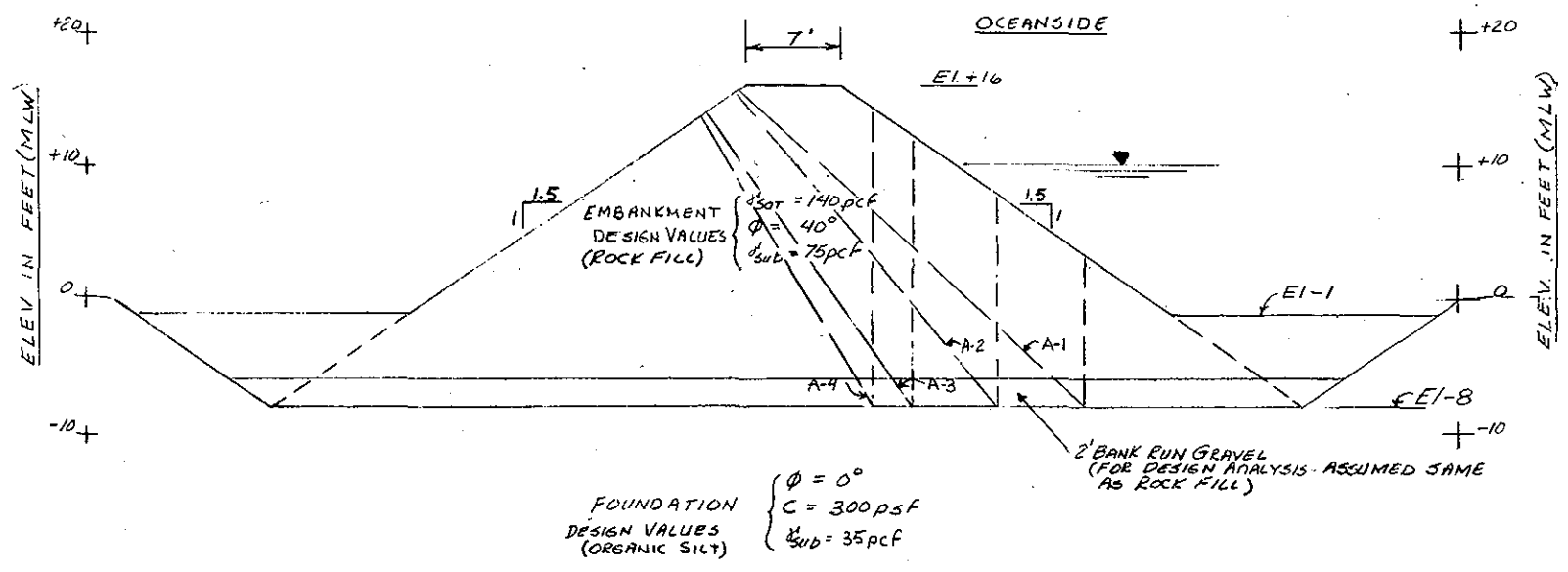
medium compact sandy gravel and gravelly sand was encountered at the location of Boring No. FD-4 at a depth of 27 to 35 feet. The soft organic silt has an average depth of about 25 feet over the easterly 1750-foot section of the structure and an average depth of about 10 feet over the westerly 1750-foot long section. Shear and consolidation tests were performed on undisturbed samples of the organic silt obtained from Boring No. FD-13. Results of these tests are shown on Plates A-5 through A-8.

13. A revised breakwater design, therefore, has been made. The revised design provides for the removal of the existing foundation materials to El. -5.0, with replacement by quarry-run stone on a 2-foot layer of bank run gravel. Utilization of bank run gravel will limit the penetration of the soft organic silt into the quarry run stone bedding course.

14. The proposed section analyzed for stability and shear failure of the foundation normal to the centerline by both the wedge and the circular arc methods, results of which are shown on Plates A-1 through A-4, indicate that the factor of safety against shear failure of the foundation normal to the centerline is adequate. As a precaution against longitudinal foundation failure during construction, the contract specifications will provide that stone and gravel materials below El. -1.0 be placed and not dumped and will precede placement of stone above El. -1.0 by at least 30 feet.

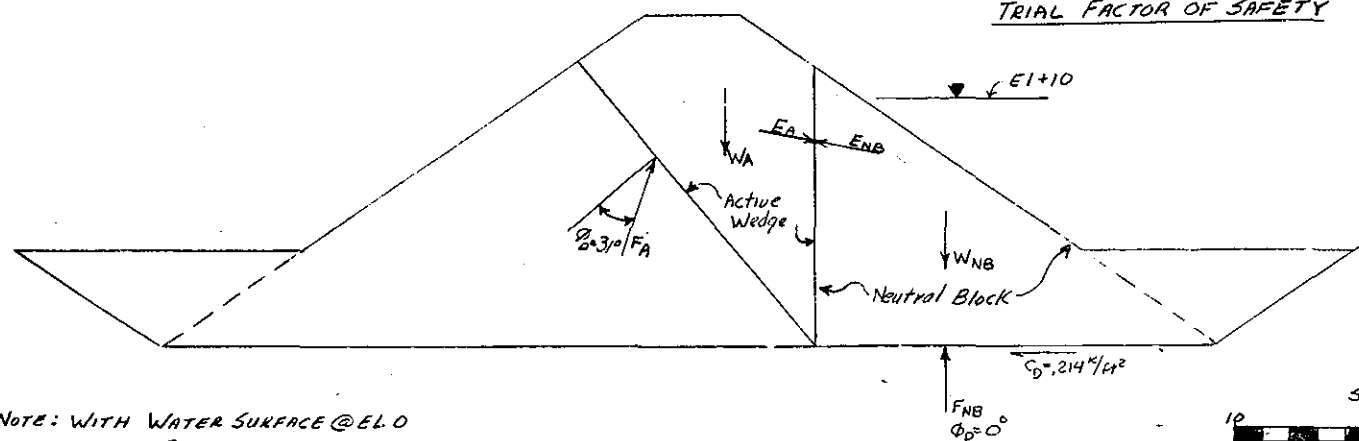
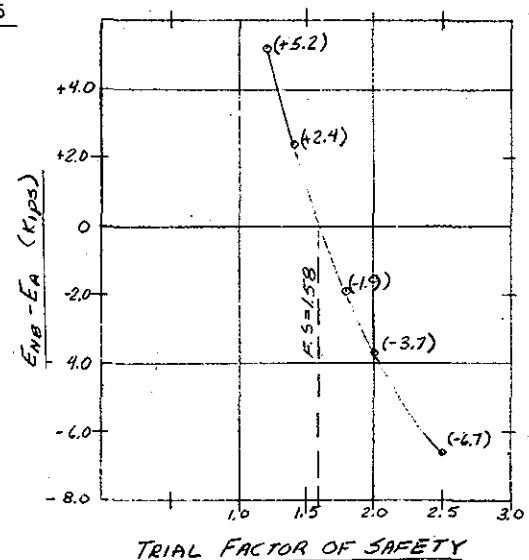
8 Incls

Plates A-1 thru A-8



### SUMMARY OF STABILITY ANALYSES

FAILURE SURFACE	FACTOR OF SAFETY
A-1	1.9
A-2	1.7
A-3	1.5
A-4	1.5



TYPICAL WEDGE ANALYSIS  
 FAILURE SURFACE A-3

### CALCULATIONS (TRIAL FACTOR OF SAFETY = 1.4)

MATERIAL	AREA (FT <sup>2</sup> )	UNIT WEIGHT (#/FT <sup>3</sup> )	CONV. FACTOR (KIPS/#)	WEIGHT (KIPS)
ACTIVE WEDGE				
ROCK FILL (ABOVE EL. 10)	82.2	140	1/1000	10.6
ROCK FILL (BELOW EL. 10)	133	75	1/1000	10.0
W <sub>A</sub> = WEIGHT OF ACTIVE WEDGE				20.6
NEUTRAL BLOCK				
ROCK FILL	372	75	1/1000	27.95
W <sub>NB</sub> = WEIGHT OF NEUTRAL BLOCK				27.95

DEVELOPED ANGLE OF INTERNAL FRICTION ( $\phi_D$ )

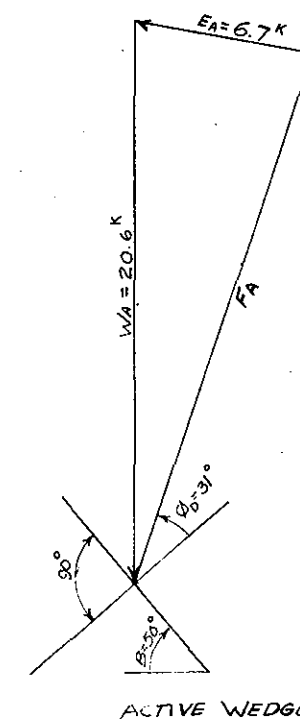
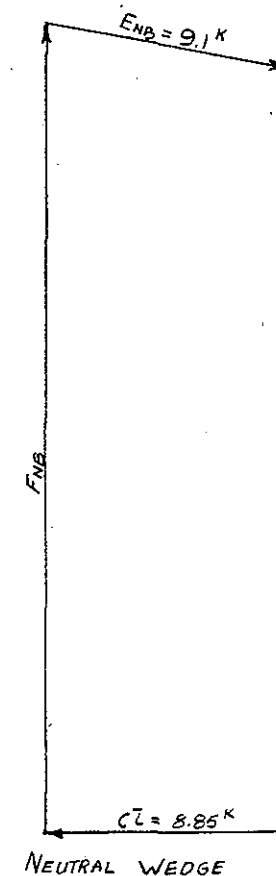
$$\tan \phi_D = \frac{\tan \phi}{F.S.} \quad F.S. = 1.4 \quad \tan \phi_D = \frac{0.839}{1.4} = 0.6$$

$$\phi_D = 31^\circ$$

DEVELOPED COHESION ( $C_D$ ) FOUNDATION SOIL.

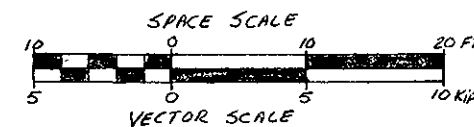
$$C_D = \frac{C}{F.S.} = \frac{300}{1.4} = 214 \text{ K}$$

$$L = 41.4' \quad C_{DL} = \overline{CL} = 41.4 \times 214 = 885 \text{ K}$$



$$ENB - EA = 9.1 - 6.7 = 2.4 \text{ K}$$

VECTOR DIAGRAMS  
 SCALE 1" = 5 K

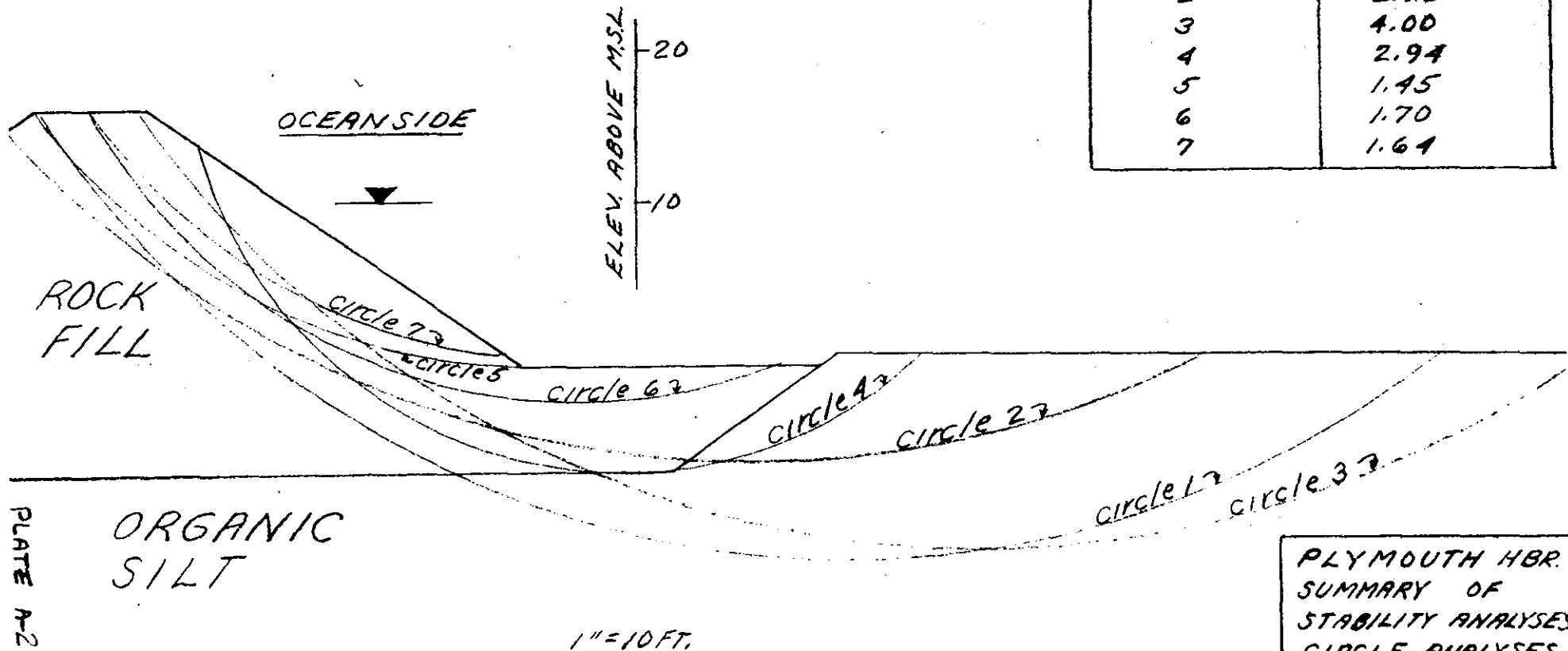


PLYMOUTH HARBOR BREAKWATER  
 PLYMOUTH MASS.

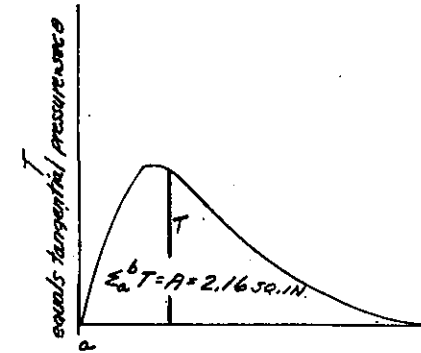
### SUMMARY OF STABILITY ANALYSIS AND TYPICAL WEDGE ANALYSIS

DESIGN VALUES			
MATERIAL	$\gamma_{SUB}$	$\gamma_{DRY}$	SHEAR STRENGTH
ROCK FILL	75 PCF	120 PCF	$\phi = 40^\circ c = 0$
ORG. SILT	35 PCF		$c = 300 PCF$

SUMMARY OF ANALYSES	
CIRCLE NO.	F.S.
1	2.40
2	2.70
3	4.00
4	2.94
5	1.45
6	1.70
7	1.64



PLYMOUTH HBR.  
SUMMARY OF  
STABILITY ANALYSES  
CIRCLE ANALYSES



VECTOR RATIO 35 PS. F. = 1.00	
MATERIAL	VECTOR RATIO
ROCK FILL (DR)	$120 \div 35 = 3.43$
ROCK FILL (SR)	$78 \div 35 = 2.23$

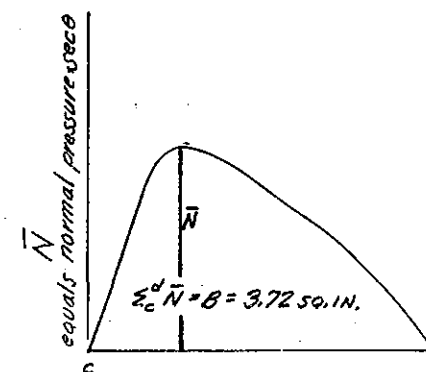
$$\text{Resisting Force} = \text{Summation } \bar{N} \tan \phi$$

$$= B \tan 40^\circ = 3.72 \times 0.839 = 3.12 \text{ sq. in.}$$

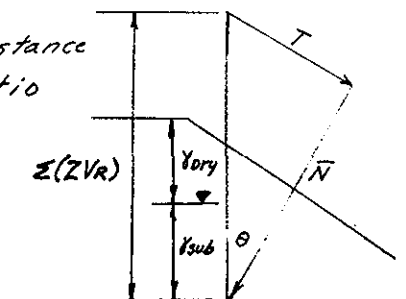
$$\text{Driving Force} = \text{Summation tangential forces}$$

$$= A = 2.16 \text{ sq. in.}$$

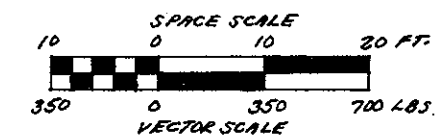
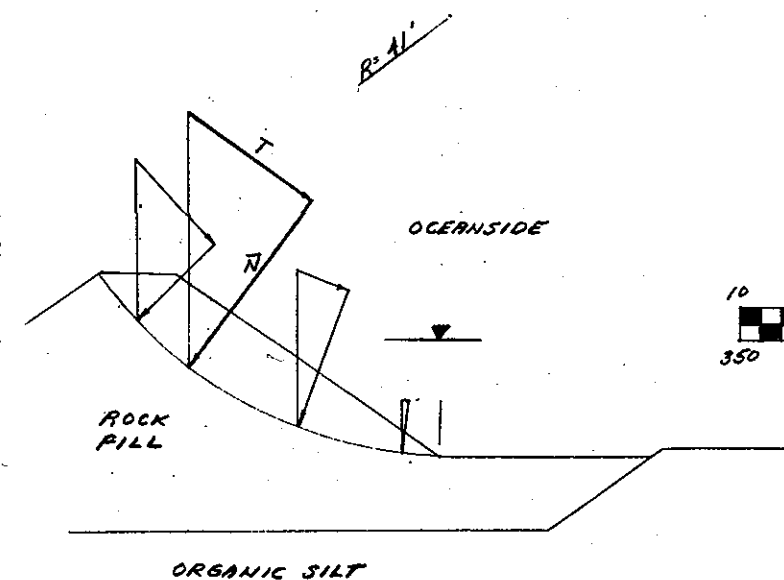
$$\text{Factor of Safety} = \frac{\text{Resisting Force}}{\text{Driving Force}} = \frac{3.12}{2.16} = 1.45$$



Z = Vertical Distance  
Vr = Vector Ratio

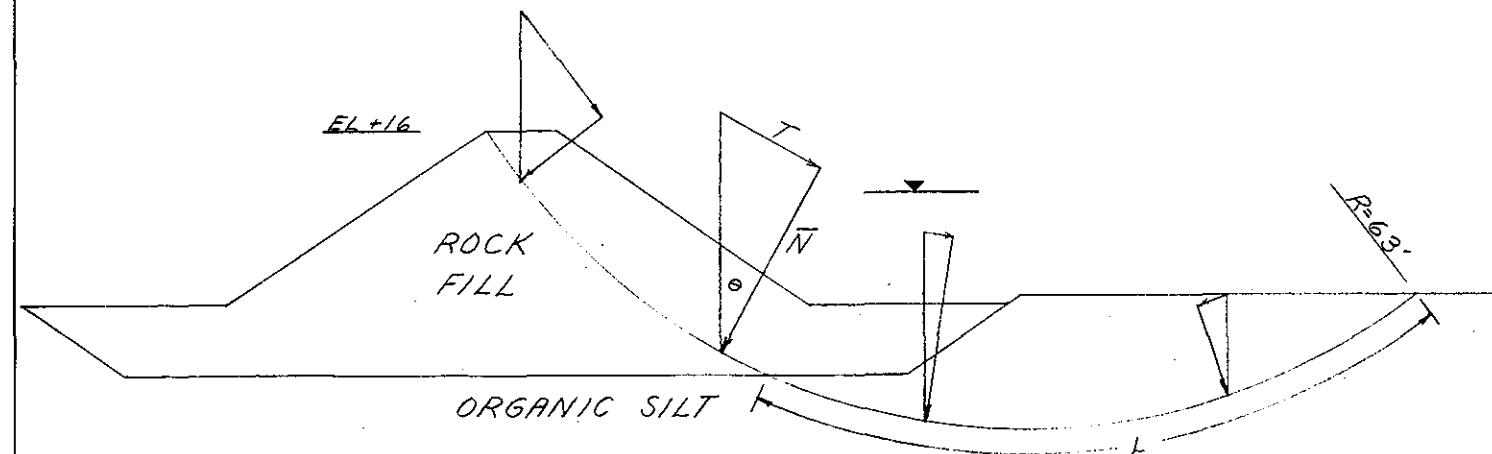
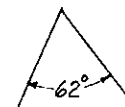
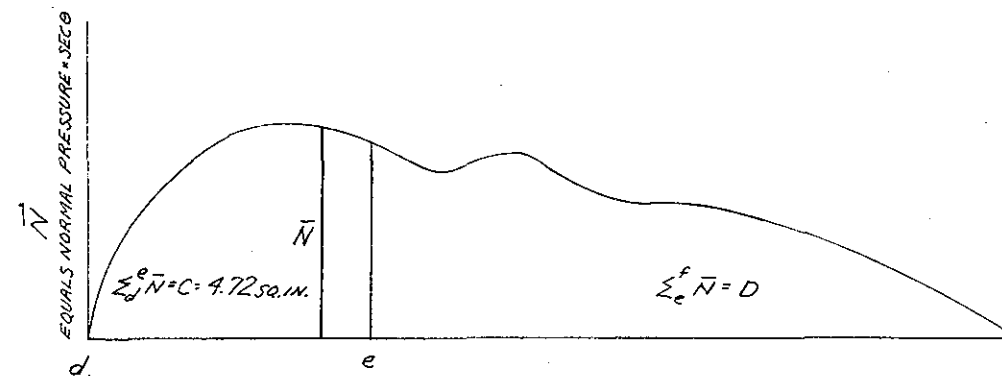
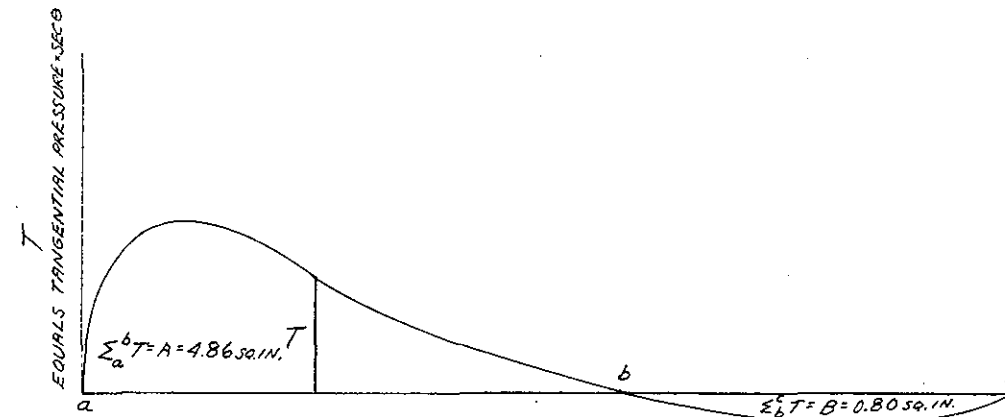


Typical Vector Diagram



PLYMOUTH HARBOR BREAKWATER  
PLYMOUTH MASS.

TYPICAL STABILITY ANALYSIS  
CIRCLE NO. 5



VECTOR RATIOS 1.00 = 35 PSF	
MATERIAL	VECTOR RATIO
ORG. SILT (SUB)	35 ÷ 35 = 1.00
ROCK FILL (SUB)	78 ÷ 35 = 2.23
ROCK FILL (DRY)	120 ÷ 35 = 3.43

Resisting Force = Summation  $\bar{N} \tan \phi + cL$

$$K = \text{Vector Scale Conversion Factor} \\ = 10 \frac{\text{FT}}{\text{IN.}} \times 10 \frac{\text{FT}}{\text{IN.}} \times 35 \frac{\text{LBS}}{\text{SQ. FT.}} \times \frac{1 \text{ KIP}}{1000 \text{ LBS}} = 3.50 \text{ K/SQ. IN.}$$

$$\int_d^f \bar{N} \tan \phi = (c \tan 40^\circ + D \tan 0^\circ) K \\ = (4.72 \times 0.839 + 0) 3.50 = 13.8^*$$

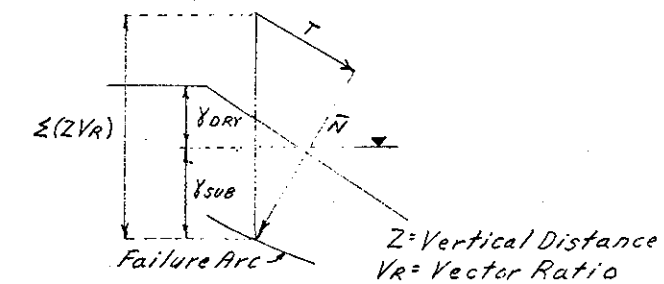
$$cL = 0.3 \times 68' = 20.3^*$$

$$\text{Total Resisting Force/FT.} = 34.1^*$$

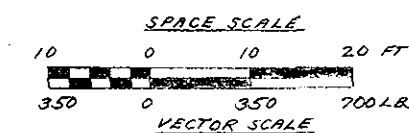
Driving Force = Summation Tangential Forces

$$\int_a^c T = (A - B) K = (4.86 - 0.80) 3.5 = 14.2^*$$

$$\text{Factor of Safety} = \frac{\text{Resisting Force}}{\text{Driving Force}} = \frac{34.1}{14.2} = 2.40$$



TYPICAL VECTOR DIAGRAM



PLYMOUTH HARBOR BREAKWATER  
PLYMOUTH, MASS.

TYPICAL STABILITY ANALYSIS  
CIRCLE NO. 1

Deviator Stress,  $\tau$ , tons/sq ft

Axial Strain, %

Shear Stress,  $\tau$ , tons/sq ft

Normal Stress,  $\sigma$ , tons/sq ft

**Shear Values**

$\phi = 0^\circ$

$\tan \phi = 0$

$c = 0.15$  tons/sq ft

Test No.		1	2	3	
Initial	Water content	$w_o$ 66.5 %	61.4 %	70.7 %	%
	Void ratio	$e_o$ 1.829	1.683	1.915	
	Saturation	$S_o$ 97 %	98 %	99 %	%
	Dry density	$\gamma_d$ 59.1	62.3	57.4	
Before Test	Water content	$w_c$ - %	- %	- %	%
	Saturation	$S_c$ - %	- %	- %	%
	Consolidation press., tons/sq ft	$\sigma_c$ -	-	-	
	Void ratio	$e_c$ -	-	-	
Final	Water content	$w_f$ 66.5 %	61.4 %	70.7 %	%
	Void ratio	$e_f$ 1.829	1.683	1.915	
Major principal stress, tons/sq ft		$\sigma_1$ 0.44	0.63	0.64	
Minor principal stress, tons/sq ft		$\sigma_3$ 0.14	0.27	0.40	
Time to failure, min		6.7	9.2	10.8	
Initial diameter, cm		7.11	7.17	7.11	
Initial height, $H_o$ , cm		16.00	16.00	16.00	

Type Test Q

Method of Saturation None ☐ Controlled Stress ☒ Controlled Strain

Type of specimen Undisturbed Rate of strain 0.06 in./min

Classification gray fine sandy organic SILT (OH)

LL 91 % PL 41 % PI 50  $D_{10}$  0.0015

Remarks Atterberg Limits and

D<sub>10</sub> based on data from

samples tested from Explor.

FD-5

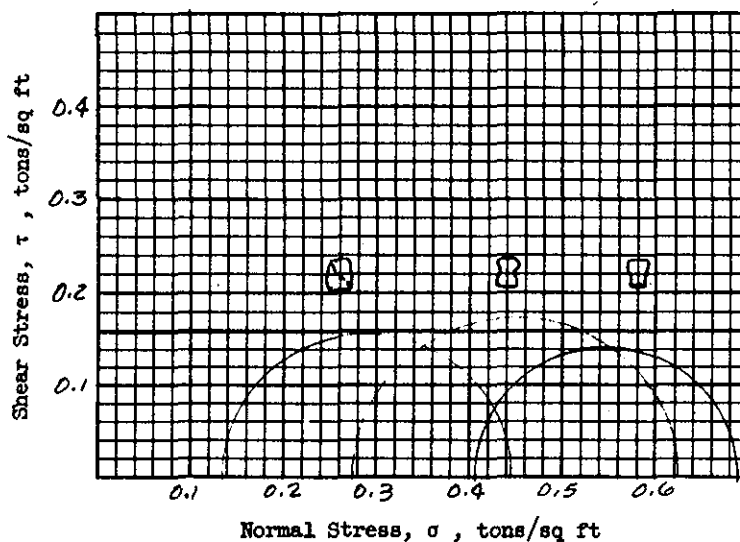
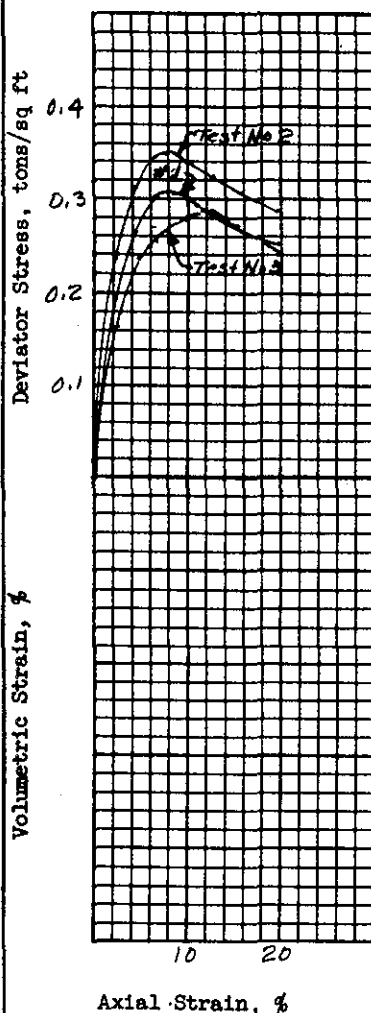
Project Plymouth Harbor

Area \_\_\_\_\_

Boring No. FD-13 Sample No. UC-7

Depth 6.0'-8.0' Date Sept. 1964

TRIAXIAL COMPRESSION TEST REPORT



Volumetric Strain, %

Axial Strain, %

Shear Values

$\phi = 0^\circ$

$\tan \phi = 0$

$c = 0.16$  tons/sq ft

Test No.		1	2	3	
Initial	Water content	$w_o$ 63.5 %	69.6 %	68.8 %	%
	Void ratio	$e_o$ 1.688	1.939	1.851	
	Saturation	$s_o$ 100 %	96 %	99 %	%
	Dry density lb/cu ft	$\gamma_d$ 62.2	56.9	58.7	
Before Test	Water content	$w_c$ - %	- %	- %	%
	Saturation	$s_c$ - %	- %	- %	%
	Consolidation press., tons/sq ft	$\sigma_c$ -	-	-	
	Void ratio	$e_c$ -	-	-	
Final	Water content	$w_f$ 63.5 %	69.6 %	68.8 %	%
	Void ratio	$e_f$ 1.688	1.939	1.851	
Major principal stress, tons/sq ft		$\sigma_1$ 0.44	0.62	0.69	
Minor principal stress, tons/sq ft		$\sigma_3$ 0.14	0.27	0.40	
Time to failure, min		9.2	8.3	11.7	
Initial diameter, cm		7.19	7.24	7.19	
Initial height, $H_o$ , cm		16.00	16.00	15.06	

Type Test Q

Method of Saturation None ☐ Controlled Stress ☒ Controlled Strain

Type of specimen Undisturbed Rate of strain 0.06 in./min

Classification organic SILT (OH)

LL 92 % PL 42 % PI 50  $D_{10}$  0.0015

Remarks Atterberg Limits and  
D<sub>10</sub> based on samples tested  
in Exploration FD-5

Project Plymouth Harbor

Area

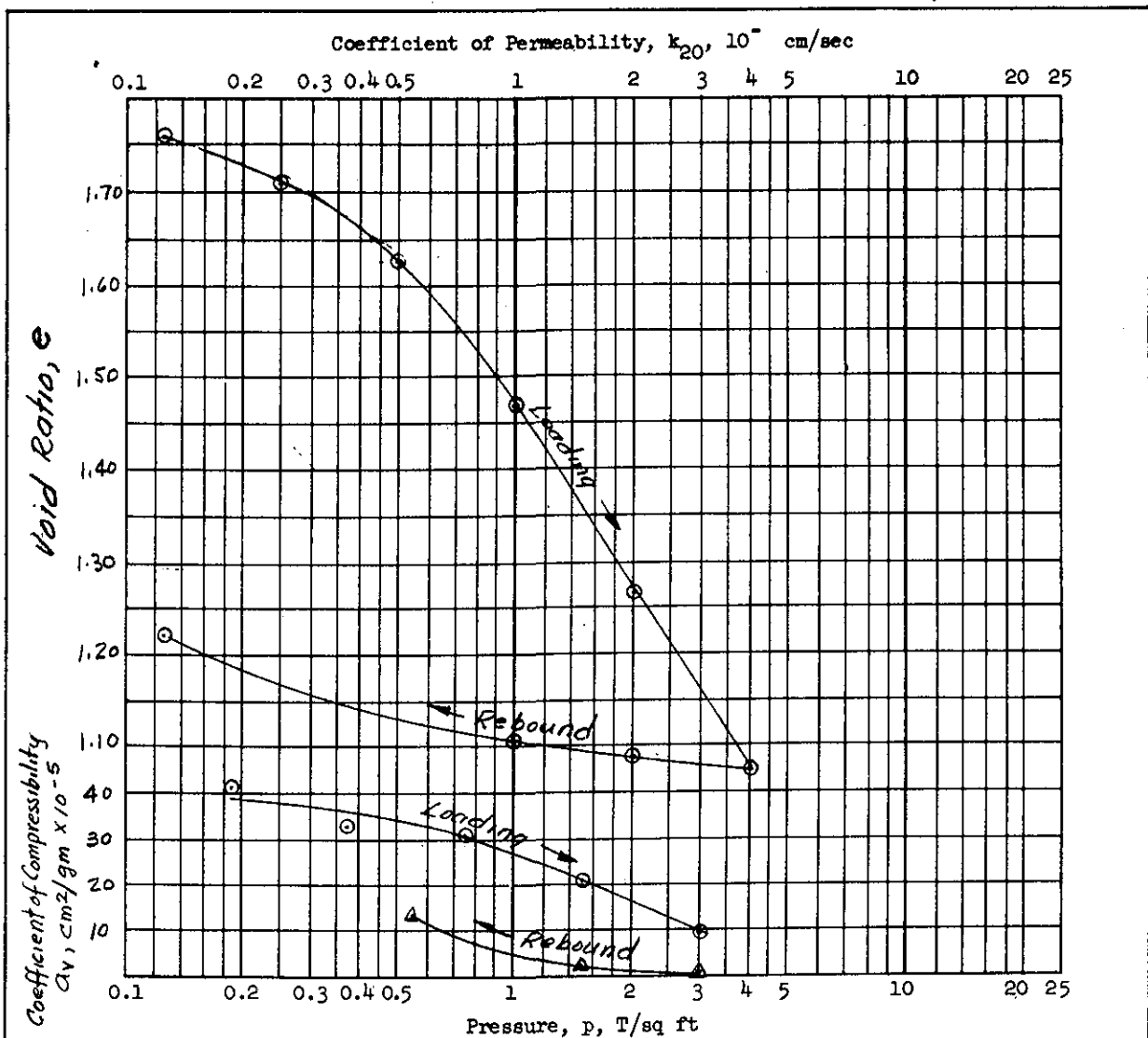
Boring No. FD-13

Sample No. UC-15

Depth 16.0' - 18.0'

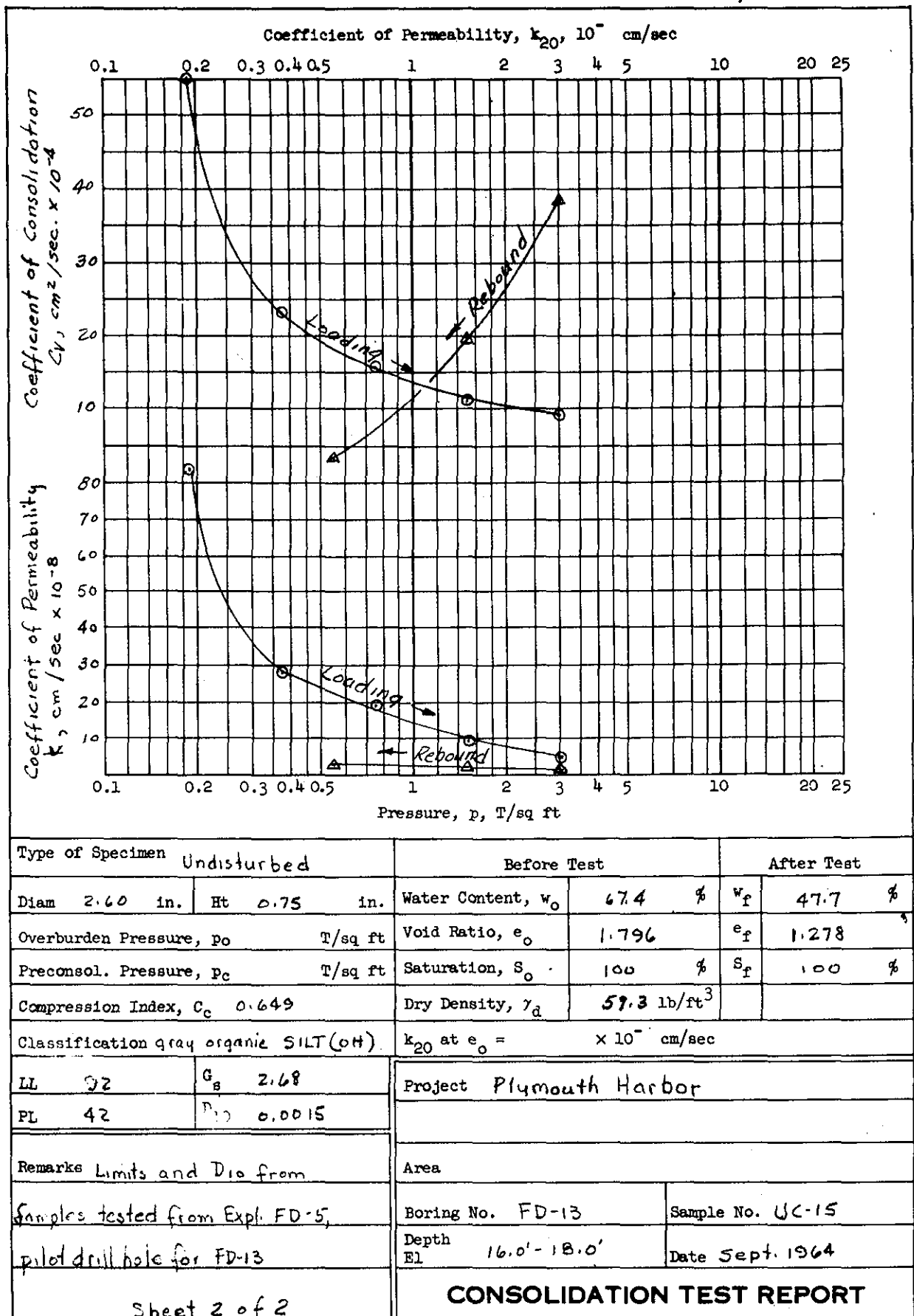
Date September 1964

TRIAXIAL COMPRESSION TEST REPORT



Type of Specimen		Undisturbed		Before Test		After Test	
Diam	2.60 in.	Ht	0.75 in.	Water Content, $w_o$	67.4 %	$w_f$	47.7 %
Overburden Pressure, $p_o$		T/sq ft		Void Ratio, $e_o$	1.796	$e_f$	1.278
Preconsol. Pressure, $p_c$		T/sq ft		Saturation, $S_o$	100 %	$S_f$	100 %
Compression Index, $C_c$ 0.649				Dry Density, $\gamma_d$	59.3 lb/ft <sup>3</sup>		
Classification gray organic SILT (OH)				$k_{20}$ at $e_o$ = $\times 10^{-}$ cm/sec			
LL	92	$G_s$	2.68	Project Plymouth Harbor			
PL	42	$D_{10}$	0.0015				
Remarks				Area			
Limits and $D_{10}$ from							
samples tested from FD-5 the				Boring No. FD-13		Sample No. UC-15	
pilot drill hole				Depth El 16.0'-18.0'		Date Sept. 1964	
sheet 1 of 2				CONSOLIDATION TEST REPORT			





DESIGN MEMORANDUM  
ON  
PLYMOUTH HARBOR, MASS.  
APPENDIX B

PROPOSED RECREATIONAL DEVELOPMENT-SPORT FISHING FROM  
BREAKWATER

1. General. - By letter of 8 June 1962, a copy of which is included in the project document report, the Assistant Secretary of the Interior suggested to the Chief of Engineers that after project authorization the project plan be modified to provide for sport fishing activities on the proposed breakwater, if subsequent studies determine that such facilities would be economically justified. The U. S. Fish and Wildlife Service estimates that a net annual benefit of \$30,000 would accrue from such use if the following modifications are made:

- "a. - That the west arm of the breakwater be terminated on shore, or a walkway from shore to the breakwater be provided,
- b. That the breakwater be capped and guard-rails and other features be provided to assure safe fishermen use.
- c. That public access and parking facilities be provided."

By letter of 26 July 1962, a copy of which is included in the project document report, the Chief of Engineers assured the Secretary of the Interior that if the project is authorized by Congress, additional consideration will be given to its fish and wildlife aspects in connection with detailed planning and design.

2. Local Interests Views. - The proposed recreational development has been discussed and the details reviewed with officials of the Commonwealth of Massachusetts and the Town of Plymouth. They have expressed their approval of the development, and the inclosed copies of letters from these agencies indicate that the required assurances of non-Federal participation, with respect to the proposed recreational development, will be met. Officials of the Town of Plymouth request that the Town be granted the right to police the structure and regulate its use for sport fishing, with such regulation to consist primarily of restricting its use during such times as it is considered unsafe.

3. Added On-Site Work. - It is considered that use of the breakwater for sport fishing will require pedestrian access to land, a

breakwater top width of 7 feet with cap-stones laid reasonably flat, and a single line of guard rail extending the full length of the structure. It will further require a pedestrian foot bridge spanning the navigation opening through the breakwater, as requested by local interests and included in the present project plan. It is noted that the project plan has been modified by adding a stone causeway about 360 feet long from the shore to the west end of the breakwater and by increasing the top width of the breakwater from 5 feet to 7 feet. The primary purpose of these modifications is to provide adequate construction facilities to allow for placement of breakwater stone above the present ground level by land equipment rather than by waterborne equipment. It is estimated that this method of construction will materially decrease construction costs and result in a substantial lessened project cost. This method of construction would probably result in the contractor's trucks, cranes and bulldozers operating from a working platform, 22 feet wide, on the structure at about one foot above mean high water (El. +10.6). In view of the above it is therefore considered that the added on-site work for the proposed recreational development would consist of the following:

- a. Widen top of breakwater above El. +10.6 by 2 feet.
- b. Raise construction causeway from El. +10.6 to El. +15.5.
- c. Construct pedestrian foot-bridge spanning navigation opening.
- d. Construct guard-rail along full length of breakwater and causeway.

4. Required Off-Site Facilities. - The recreational development will require public access to the land terminous of the breakwater, and adequate parking and sanitation facilities to accommodate the sport fishermen, including operation and maintenance of these facilities throughout the project life. The U. S. Fish and Wildlife Service estimate that 50 to 100 fisherman will use the breakwater at the same time. It is estimated that about 20,000 square feet of parking area, within a reasonable distance of the shoreward end of the breakwater, will be required, assuming peak capacity of 100 fishermen, that all fishermen will travel to site by car, and that each car will carry two people. Present public parking facilities in the area consist of a Town of Plymouth paved metered parking area, with a capacity of about 150 cars.

off Water Street about 1000 feet from the shoreward breakwater terminus, and an unpaved but graded area suitably for parking use, of about 3 acres, owned by the Town of Plymouth, adjacent to the terminus, which would accommodate about 300 cars. There are existing public sanitation facilities, owned, operated and maintained by the Town of Plymouth, located at the Memorial Building, a distance of about 1500 feet from the terminus, and at the State Pier, a distance of about 2500 feet. These parking and sanitation facilities are open to all on equal terms and are considered adequate not only to accommodate their present users but also to accommodate the sport fishermen who will use the breakwater. To assure public access for the proposed recreational development will also require that a parcel of Town-owned property about 400 feet long and 15 feet wide, running from Water Street to the breakwater terminus, be made a public right-of-way for the life of the project. It is expected that the Town will charge a nominal amount for the use of the above parking and sanitary facilities, thus placing the cost of maintenance and operation on a self-liquidating basis.

5. Cost Estimate. - The estimated cost for accomplishment of the proposed recreational development is based on prices prevailing in Sept. 1965. Annual charges are based on a project life of 50 years and the estimate of maintenance represents the expected requirements during that period, expressed in terms of the annual average.

#### First Costs of Recreational Development

##### On-site Work

Widen top 5 ft. of breakwater by 2 ft.	
1300 ton stone x \$5.60 =	\$ 7,300
Raise construction causeway by 5 ft.	
1400 ton stone x \$5.20 =	7,300
Construct pedestrian foot-bridge 1.s. =	6,500
Construct guard-rail	
3,800 ft. x \$2.00 =	7,600
	<u>\$28,700</u>
Contingencies (12%)	3,400
	<u>\$32,100</u> say
Total Constr. Cost	\$32,000
Engineering & Design	1,000
Supervision & Administration	<u>2,000</u>

\$35,000

Estimated Value of Additional Off-Site Lands and Provision of Basic Facilities

Graded parking area	20,000 s.f. x \$0.55 =	\$11,000	
Public right-of-way	6,000 s.f. x \$0.55 =	3,300	
Sanitation facilities (est. value)		6,000	
		<u>\$20,300</u>	say <u>\$20,000</u>

Total Est. First Costs of Recreational Development \$55,000

Annual Charges (50-year life @ 3-1/8% interest)

Interest & Amortization (\$55,000 x .03979)		\$ 2,200
Maintenance & Operation -		
Foot-bridge maintenance	\$1,000	
Guard-rail maintenance	1,000	
Parking area & sanitation facilities, operation & main.	<u>none</u>	
		<u>2,000</u>
Total Est. Annual Charges		\$ 4,200

Annual Recreational Benefits. - Annual benefits resulting from the use of the breakwater for sport fishery have been estimated by the U. S. Fish and Wildlife Service to be \$30,000.

6. Economic Evaluation. - The estimated annual charges for the proposed recreational development in the amount of \$4,200 and the estimated annual benefits in the amount of \$30,000 result in a benefit-cost ratio of 7.1. It is therefore concluded that the proposed development is economically justified.

7. Cost Sharing. - The present policy of the Corps of Engineers with respect to the development of recreational facilities at authorized Federal breakwater projects requires that the non-Federal entity shall bear at least 50 percent of the total first cost of the recreational development, plus, operation and maintenance of supporting facilities throughout the project life, e.g., access, pedestrian bridge, parking and sanitation facilities. The non-Federal share may consist of the appraised value of the additional lands which they are required to provide, the value for provision of basic facilities, and fair market value of labor, equipment and material for acceptable work in kind. In this particular case, since maintenance of the breakwater is entirely Federal,

maintenance of the recreational facilities, e. g., guard-rail, foot-bridge, integral with the breakwater, will also be Federal. Application of this policy in this case results in the following apportionment of the first costs:

Total estimated first costs (see Par. 5)	\$55,000
Federal share (50%)	27,500
Non-Federal share (50%)	27,500
Credit to non-Federal interests for furnishing additional off-site lands and provision of basic facilities, e. g., access, parking & sanitation facilities (see Par 5)	<u>20,000</u>
Required Non-Federal contribution	\$ 7,500
$\% \text{ of non-Federal contribution } \frac{7,500}{34,000} = 22\% \text{ say } 20\%$	

8. Requirements of Local Cooperation. - Recommended requirements of local cooperation in connection with a recreational development, to provide for sport fishing facilities on the breakwater, are as follows:

a. Contribute in cash 50 percent of the first cost of construction of the on-site project recreational development features, less the value of basic facilities required to provide for sport fishing from the breakwater, e. g., public access, parking and sanitation facilities

b. Provide, without cost to the United States, a public right-of-way at least 15 feet wide extending a distance of about 400 feet from Water Street to the westerly end of the breakwater.

c. Provide, operate and maintain, without cost to the United States, adequate parking and sanitation facilities, within a reasonable distance of the breakwater, to accommodate, on equal terms, all those fishermen using the breakwater during the estimated project life of 50 years.

d. Hold and save the United States free from damages resulting from personal injury to any person while engaged in fishing from the breakwater, with the understanding that the Town of Plymouth is authorized to police, regulate, restrict or limit, in the interest of public safety, the use of the breakwater for sport fishing activities, providing that such regulations, restrictions and limitations are applicable to all on equal terms.

DESIGN MEMORANDUM  
ON  
PLYMOUTH HARBOR, MASS  
APPENDIX C

ANALYSIS OF PROJECT PLAN

Based on 100-Year Project Life - (Information Called for by Senate  
Resolution 148, 85th Congress)

First Costs of Construction (Feb. 1966 Price Level)

Dredging:

Within anchorage area		
649,000 c. y. x \$1.05 =	\$682,000	
Within breakwater foundation		
50,000 c. y. x \$1.05 =	<u>52,500</u>	
		\$ 734,500

Stone Furnished and Placed:

In breakwater		
181,300 ton x \$5.60 =	1,015,300	
In Causeway		
9,500 tons x \$5.20	49,400	
Gravel Borrow Furn. & Plac.		
In b'k'r found. 28,500 ton x \$2.80	<u>79,800</u>	1,144,500
Guard-rail 3800 l.f. x \$2.00		7,600
Foot-bridge lump sum		<u>6,500</u>

\$1,893,100

Contingencies (12%)

227,100

Total Contract Cost

2,120,200

Engineering & Design

65,000

Supervision & Administration

140,000

2,325,200

Total Project Construction Cost say

\$2,325,000

Aids to Navigation (Coast Guard)

1,000

Est. value of basic facilities for recreational  
development, e. g., public access, parking  
& sanitation facilities

20,000

\$2,346,000<sup>(1)</sup>

Corps of Eng. Total Cost \$1,860,000

Coast Guard Total Cost 1,000

Non-Federal Interests Total Cost 485,000

(1) Exclusive of \$10,000 Preauthorization Studies

Annual Charges (100 yr. life @ 3-1/8% interest)

Federal

Corps of Engineers

Interest & Amortization

(\$1,860,000 x .03276)

\$60,900

Maintenance - to breakwater

8,000

to foot-bridge

1,000

to guard-rail

1,000

anchorage dredg-  
ing

10,000

20,000

\$ 80,900

U. S. Coast Guard

Interest & Amortization

(\$1,000 x .03276)

30

Maint. - Aids to Navigation

170

Total Federal

200

Non-Federal

Interest & Amortization

(\$485,000 x .03276)

14,900

Total Annual Charges

\$ 96,000

Annual Benefits (see Par. 39 of the main body of this report)

Navigation & Recreational Development -inc. redevelopment benefits

\$168,850

Navigation & Recreational Development -excl. redevelopment benefits

\$163,150

Benefit-Cost Ratio

Incl. area redevelopment benefits - \$168,850/\$96,000 = 1.7

Excl. area redevelopment benefits - \$163,150/\$96,000 = 1.6





TELEPHONE  
746-0402

AREA CODE 617

TOWN OF PLYMOUTH  
OFFICE OF  
THE SELECTMEN

11 LINCOLN STREET  
PLYMOUTH, MASSACHUSETTS 02362

SELECTMEN

SUMNER A. CHAPMAN, JR., CHAIRMAN  
WILLIAM H. BARRETT  
GEORGE E. RANDALL  
DENNIS L. COLLARI  
EDWARD J. WILSON

September 22, 1965

E. J. Ribbs, Colonel, Corps of Engineer  
Deputy Division Engineer  
U.S. Army Engineer Division, New England  
424 Trapelo Road  
Waltham, Massachusetts 02154

Re: Federal Navigation Project  
Plymouth Harbor Mass., NEDED-R

Dear Colonel Ribbs:

This is a belated reply to your letter dated August 19, 1965, regarding the above project. Delay was due in part to the difficulty of obtaining a definite answer to the questions contained in your letter.

The latest information available to me, is that funds were to be sought from the Federal Government under one of the newer economic redevelopment plans to obtain substantial assistance in the construction of a complete sewage treatment project.

The Plymouth Sewage Disposal Committee has been investigating the possibilities and has been given substantial ground to believe that funds will be made available and that the proposed project will meet requirements of the Federal Government as well as the State.

The Committee is confident that before the annual town meeting in March, it will be able to submit complete plans for a project including a request for an approval of an appropriation sufficient to undertake it. However, should further delay be necessary before presenting the complete project, the Committee is prepared to submit to that town meeting an article requesting approval of an appropriation of funds sufficient to construct a temporary outfall which would carry the sewage beyond the area enclosed by the breakwater and extend it far enough to reduce or eliminate the likelihood of sewage being pocketed by the

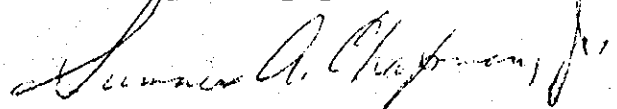
Federal Navigation Project, Plymouth Harbor NEDED-R  
E. J. Ribbs, Colonel, Corps of Engineers September 22, 1965

breakwater when completed.

In regard to the proposal to add to the project a recreational development as outlined in your letter above mentioned, I have every reason to believe the Town of Plymouth will be willing to meet the requirements of local cooperation which you set forth and to add to the project the recreational development to provide sport fishing facilities which you describe.

I think this answers all your questions as far as I am able to do so at this time. I am very grateful for the information supplied in your letter and shall assume, pending further advice from your office that the dredging and breakwater project will be undertaken upon schedule, as indicated.

Very truly yours,



Sumner A. Chapman, Jr.

SACJR/a



# *The Commonwealth of Massachusetts*

## *Department of Public Works*

### *Division of Waterways*

*100 Nashua Street, Boston 02114*

March 3, 1965

E. J. Ribbs, Colonel  
Acting District Engineer  
Corps of Engineers, New England Division  
424 Trapelo Road  
Waltham, Massachusetts 02154

Dear Colonel Ribbs:

Reference: NEDLD-R

Reference is made to your letter dated February 25, 1965, concerning the Federal Improvement at Plymouth Harbor.

We are heartily in accord with your proposal to schedule dike construction after the existing 14" sewer outfall is extended beyond the limits of the basin or until the proposed treatment plan and new outfall are completed and in operation. Unless this is done, we would have a condition in Plymouth Harbor that nobody would want to live with.

The sport fishing proposal poses some questions as far as the Division of Waterways is concerned. We have always taken the position that breakwaters are accident prone structures and the public should be discouraged from using them for any purpose. I personally feel that Fish and Wildlife's figure of 20,000 people annually fishing from this structure is extremely optimistic. However, I suppose that if Town authorities desire this addition, are willing to pay half of the local cost, and will assume all responsibility for all accident and damage claims, the Board of Commissioners would act favorably on the added cost.

Very truly yours,

*John T. Hannon*  
JOHN T. HANNON  
Deputy Chief Engineer